February 2015

The Uinta Express Pipeline:

A Comprehensive Research Report Conducted by Students Enrolled in CvEEN 3100 Technical Communications

Department of
Civil & Environmental Engineering
THE UNIVERSITY OF UTAH

EXECUTIVE SUMMARY

The Uinta Express Pipeline is a proposed common carrier pipeline which would transport waxy crude oil extracted from the Uinta Basin in northeastern Utah to area refineries in North Salt Lake City. The proposed project would consist of a 12-inch, buried, insulated, carbon steel pipeline supported by numerous ancillary facilities along its approximately 135-mile long route. Tesoro Refining and Marketing LLC, the principle organization sponsoring research and development of the Uinta Express Pipeline, claims that once operational it will have the capacity to transport up to 60,000 barrels of unrefined waxy crude oil daily, thereby removing an estimated 250 semi tanker trucks from Utah's highways each day.

This Report, compiled by University of Utah students enrolled in CvEEN 3100: Technical Communications, thoroughly interrogates the proposed pipeline with current research and specification data. Students enrolled in CvEEN 3100 during the Fall 2014 semester identified various aspects of the proposed project that presented the most significant challenges from a civil and environmental perspective. Students worked in teams to compile feasibility reports, which comprise the individual chapters. Teams coordinated with one another to ensure that research content, images, and technical data discussed in one chapter did not overlap with material in other chapters.

This Report is divided into two sections. Section I investigates the planning, policy, and environmental issues associated with the pipeline while Section II analyzes characteristics of the waxy crude oil as well as the components, infrastructure, and maintenance of the actual pipeline. Chapter 1 examines "Construction Planning, Management, and Land Acquisition" concerns of the proposed pipeline. Chapter 2 analyzes the market conditions associated with "Economic Impact and Policy" issues relating to local residents, the Utah state budget, as well as the contribution the pipeline makes in reducing federal dependence on foreign oil. Chapters 3 and 4 research potential environmental impacts the pipeline will affect should construction be approved. Chapter 3 "Environmental Impacts: Vegetation, Wildlife, and Wetlands" offers a comprehensive view of flora and fauna impacts along the proposed route, while Chapter 4 "Water Quality: Spill Hazards" studies local water quality concerns, including ground water, creeks and rivers, and watershed reservoirs.

Section II begins in Chapter 5 with a detailed account of the "Front End Production" of waxy crude oil, including extraction techniques, while characterizing the unrefined product as well as the geological formations wherein the crude is located. Chapter 6, "The Pipeline and the Power Usage" is perhaps the most robust chapter of the report as it models ancillary facilities of the proposed route while calculating power demands, fluid flows, head loss, heating elements, and other critical factors associated with transporting the product long distances. Chapter 7 "Pipeline Maintenance" offers an in-depth account of maintenance issues and equipment such as different types of scrappers and their functions. Chapter 8 concludes with an analysis of the "Refinement Process" beginning with how the waxy crude oil is handled once it enters the refinery as well as what happens to the final products once leaving the refinery.

EDITOR'S PREFACE

While I facilitated the composition of this Report from its initial, conceptual stages to compiling the individual chapters into one document, the students deserve credit for this final draft. I witnessed every single student in the course make significant contributions to his or her individual sections; similarly, each team displayed a tremendous amount of self-motivation, invention, and determination to fit their work into a much larger document.

Since this Report is a compendium of student writing, I have made every effort to maintain the tenor and style of their individual writing. At times, however, I have made slight revisions and omissions from the original drafts that students submitted in partial fulfillment for their final grade. Any changes I made to their original work occurred within three general categories: redundancy, language use/ grammar, and formatting.

> Redundancy Occasionally, throughout the document, certain words or phrases would appear either out of context or in an inopportune place such as a title or subheading. The most common example of redundancy occurred with the phrase Uinta Express Pipeline or UEP. For example, Chapter 4 was originally titled "Water Quality: Spill Hazards of the UEP." Since each chapter is about the UEP as indicated by the title of the final report, I deleted the phrase "of the UEP" so as to maintain the students' original language while omitting needless repetition.
>
> Language use/ Grammar While finalizing this report, a spelling or grammatical error would appear, and I indiscriminately accepted/ rejected certain suggestions. I must be clear: I did not proofread the document. Rather, if I noticed a glaring typographical error while scrolling through a page, I made minor changes.
>
> Formatting The most significant edits I made involved formatting or organizational changes. Even though a numbering schema was agreed upon, occasionally a section was numbered incorrectly. For example, if a team labeled their Introduction 1.0 as opposed to 1.1, I manually changed the numbering throughout the chapter to ensure for overall consistency. Such changes no doubt have affected in-text referencing, etc. Other instances occurred when a sentence, passage, or image needed to be shortened in order that a subheading laid out correctly on a page. In each case, I tried to maintain the integrity of the original content, while editing only as much as required of the report format.

This Report represents a serious attempt by undergraduates to combine the technical writing skills we studied in the course of a semester with the expectation and level of expertise required of civil and environmental engineering students. The students, for their part, were professional, serious, and intelligent, and I am immensely proud of the work they accomplished in the six weeks we spent drafting and revising each chapter.

Joshua B. Lenart, Ph.D.
Salt Lake City, UT
February 2015

TABLE OF CONTENTS

Cover Image: Tesoro Refinery, Salt Lake City, UT, US
Photo Credit: Resistance Ecology, "Moscow, Idaho: Fighting Fossil Fuel Infrastructure in the Northern Rockies," ed. Resistanceecology.org, 2013.

Chapter 1

Construction Planning, Management, and Land Acquisition

Abstract
The Uinta Basin, Utah's largest producer of crude oil, continues to produce oil at an ever increasing rate. The oil that is produced in the Uinta Basin is high-paraffin waxy crude oil, whose unique properties cause the oil to harden at room temperature. Oil refineries in Salt Lake City are the primary consumers of the oil produced in the Uinta Basin, and, as of right now, the only method of transportation for the oil is by tanker truck since existing pipeline infrastructure cannot effectively transport the waxy crude due to its properties. As production increases, so, too, will truck traffic, and a major concern is the ability of existing highway infrastructure to safely manage the associated truck traffic. The Uinta Express Pipeline Company, a subsidiary of Tesoro, has proposed to construct a pipeline from the Uinta Basin to Salt Lake City to handle the increased production of crude oil while removing tanker trucks from the road.

The construction portion of civil infrastructure projects is what turns plans into reality. This chapter will examine the effective management strategies and planning of the construction and land acquisition aspects of the Uinta Express Pipeline. Managing the construction phase of the pipeline will ensure safe, timely, and cost-effective completion of the project. Along with management of construction, scheduling of the individual tasks that need to be completed, from the Environmental Impact Statement to reclamation, is critical to getting the project done on schedule and not going over the budget of the project. Other aspects of the construction phase that need assessment include the awarding of contracts to contractors for the various tasks and site inspections before, during, and after construction. Aside from the construction of the pipeline itself, consideration must be taken to ensure all legalities are met and proper easements are obtained in the acquisition of the land on which the pipeline is to be built. Pipeline construction should follow all rules and regulations while keeping the best interest of all involved parties.

1.1 Introduction

For the foreseeable future, the energy demands of the United States will continue to be met by the burning of fossil fuels. Utah, the US's ninth biggest producer of crude oil, gets approximately 70 percent of its oil and gas from the Uinta Basin [1]. The oil supplied by the Uinta Basin already serves as an important source of Utah's, and the US', energy, and the production and importance of the area is only expected to increase [1]. It is estimated that oilfield industry is responsible, directly or indirectly, for half of all jobs in the area [1]. The majority of the crude oil produced in the Uinta Basin is a type unique to the region – high-paraffin waxy crude oil.

1.1.1 Purpose and Need

The properties of waxy crude oil pose a significant challenge when it comes to transporting the raw material. At room temperature waxy crude will harden, so, during transportation, the oil must be kept above certain temperatures. The primary consumers of Uinta Basin oil are refineries located in the Salt Lake City area, and the mode of transportation to these refineries is by tanker truck. Between 2008 and 2013 the production of crude oil in the Uinta Basin increased by approximately 54 percent, to an estimated 18 million barrels [2]. As drilling technology continues to accelerate and more oil becomes economically feasible to extract, the crude oil production of the area will continue to increase [2].

The truck traffic associated with the increase in production poses some fundamental problems to the highway infrastructure that would be tasked with handling the trucks. A major concern is the ability of the existing roadway to safely manage the truck traffic. It is clear that other options for the transportation of the crude should be explored, and a suggested solution is the construction of a new pipeline. Existing pipeline infrastructure cannot effectively transport the waxy crude because of its unique properties. Thus, a 12 inch, insulated, heated pipeline has been proposed by Uinta Express Pipeline Company in order to effectively handle the increased production of crude in the area and remove tanker trucks from the road.

1.1.2 Purpose of the Report

The construction of a civil infrastructure project is what turns a plan into a finished product. Effectively managing the construction phase of any project is crucial to the project's successful completion, and, in order to successfully complete the proposed pipeline, civil engineers will play a critical role overseeing construction operations and ensuring all legalities of the land acquisition for the pipeline are taken into account. This report outlines the entire process of constructing the pipeline from the Environmental Impact Statement to the reclamation of the disturbed land at the conclusion of the construction process. Along with the determination of individual tasks that need to take place, the report defines the schedule that construction should follow to ensure timely, efficient, and cost-effective completion of the project. Another aspect of construction that the report analyzes is the management of construction operations during the project, essentially establishing a chain of command that will ensure satisfactory completion of the pipeline while remaining on schedule. Also discussed in the report is the process of legally acquiring rights to the land where the pipeline is to be constructed so that the project follows all rules and regulations, avoiding any possible penalties and setbacks.

1.2 Land Rights

The construction of the pipeline is not able to begin without first having an established route. Settling on a route selection that pleases all of the parties involved (i.e. The Bureau of Land Management, The United States Forest Service, private parties, etc.) is not a simple process. No group of people necessarily wants to give up portions of their lands; however, under certain statutes of the law, this may be inevitable.

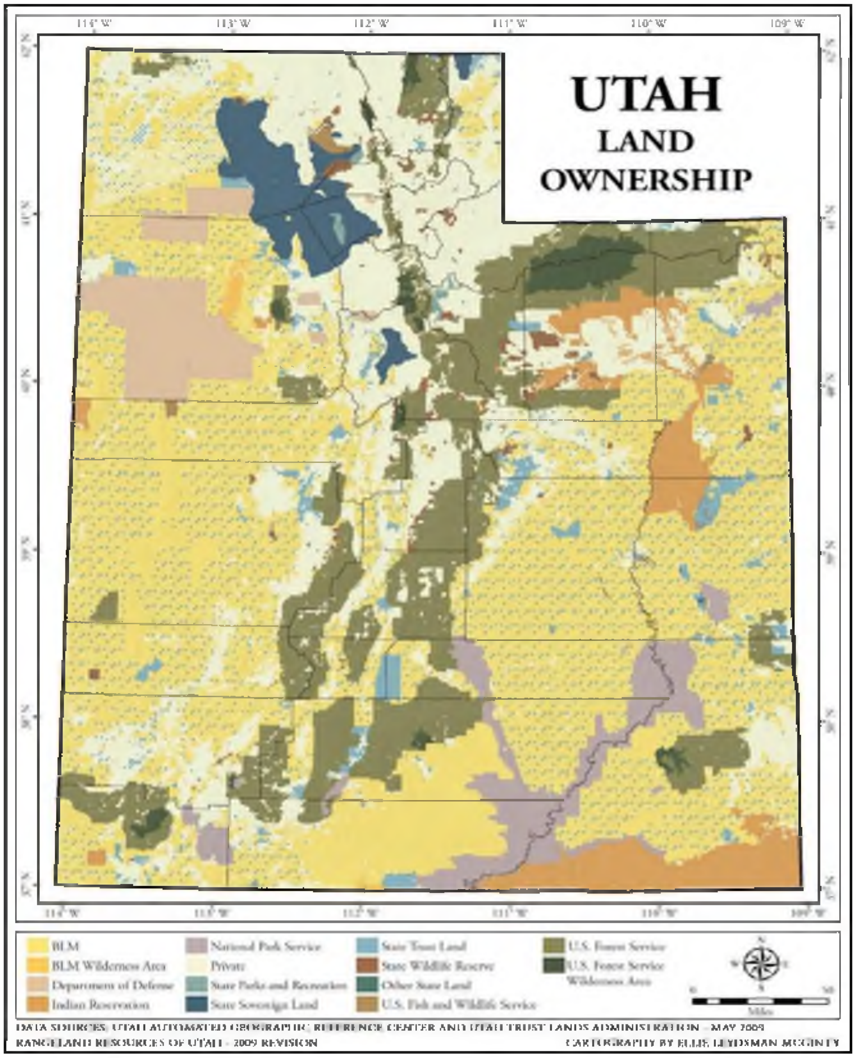


Figure 1.1: Utah Land Ownership: Different land ownership illustration for Utah [3].

Figure 1.1 illustrates how the state of Utah is divided in terms of ownership. Each proposed route of the pipeline would cross different sections of the state which are owned by different parties. Determining routes based off the ownership of the lab is further discussed in sections below.

1.2.1 Northern Route

There are three proposed routes that branch off of one another at Francis, UT. The northern route crosses both US Forest Service land as well as privately owned land, majorly private. In order to obtain this land for the use of the pipeline, there are different actions that need to take place depending on the ownership of the land.

1.2.2 Permitting and Redistribution of Ownership

In order to obtain land to use, the US Forest Service would need to sign and issue a permit. "That is the NEPA (National Environmental Policy Act) process. NEPA requires that Tesoro provide alternative routes for the pipeline and conduct a scoping process which leads to an Environmental Impact Statement (EIS). Based upon that EIS, the Forest Service will identify an acceptable pipeline route through federal lands" [4]. The EIS also looks at the impacts it makes on not only federally owned land, but private as well. If the pipeline is not suitable in any of the areas, in terms of the environmental impact, then the US Forest Service reserves the right to deny any rights to the land. When discussing private land, the process is quite different and does not need such permitting, but instead eminent domain must be considered.

1.2.2a Eminent Domain

Eminent domain is defined as "the power possessed by governments to take over the private property of a person without his/her consent. The government can only acquire private lands if it is reasonably shown that the property is to be used for public purpose only" [5]. This means that the state can freely take privately owned land whenever they desire with the purpose of serving the public as a whole.

1.2.2b Utah Judicial Code

When reviewing the Utah Code, specifically the Judicial Code, 78B-6-501 6a states this certain circumstance in which eminent domain can be exercised: "roads, railroads, tramways, tunnels, ditches, flumes, pipes, and dumping places to access or facilitate the milling, smelting, or other reduction of ores, or the working of mines, quarries, coal mines, or mineral deposits including oil, gas, and minerals in solution" [6]. This clause indicates that taking private land will not be an issue when trying to locate the placement of the pipeline.

1.2.2c Effect on Citizens

If the government can take any privately owned land for the purpose stated above, then the land owners simply have no input according to the law. This leaves many citizens questioning whose land will be compromised and how much of it. Since all of the proposed routes west of Kamas go through mostly private land, this eminent domain will have to be exercised. This does not necessarily mean that all of the land will be taken away from the owner, but just as much as the government sees suitable for this project.

1.2.3 Southern and East Canyon Routes

The other routes are only slightly different. The southern route would follow the northern route for the first 90 miles and then go south to make this the shortest route. The east canyon route "would be 135 miles and would follow the northern route for the first 90 miles, then bearing west to Park City. From there, it would parallel East Canyon Creek, joining with the Kern River pipeline at the top of the Wasatch Range, finishing the same as the northern route in Salt Lake" [4].

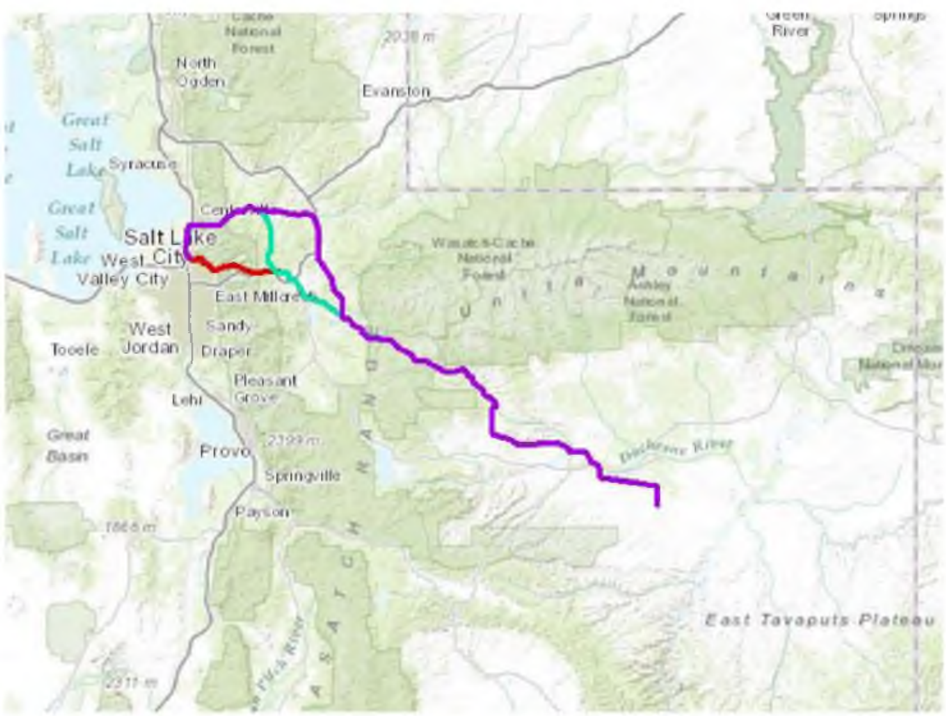


Figure 1.2: Proposed Routes: Three proposed routes for the pipeline [7].

1.2.4 Route Selection vs. Land Ownership

By observing Figure 2 and comparing it with Figure 1, the northern route would cross far more private land than any other type. With this route selection, eminent domain would have to be exercised and more settlements would have to be paid out. Similarly, the southern route and the east canyon route cross majorly private land; however, the southern route crosses into US Forest Service land and the east canyon route crosses land owned by the State Wildlife Reserve. Crossing through the US Forest Service land will require NEPA to take effect as previously discussed in Chapter 1.2.2. Crossing through State Wildlife Reserve land will require something similar in terms of processing an EIS. The route through this specific area will be determined by what the State sees suitable with respect to the effects left on the environment as well as potential other routes through this section of land.

1.2.4a Optimal Route

Route selection will be determined in coordination with the EIS. This process has yet to conclude which leaves a lot of speculation for what the final decision will be. However, with a thorough analysis of each type of land and how much of it will cross, the northern route would be better suited for the pipeline. It would not cross as much US Forest Service land as the southern route which would require less permitting for this section. The east canyon route crosses through a wildlife reserve. The northern route would not have to disrupt any sort of functioning ecosystem within an area that is already designated as a wildlife habitat. Eminent domain would be the only concern of this route which is something that all routes contain. For this reasoning, the northern route would be the ideal route for such a pipeline.

1.3 Construction Management

A construction management team generally consists of a construction manager, contractor representative, designer/engineering team member, and someone representing the owner. It is quite common for these three members to have several people assisting them in each of their responsibilities. The goal of any construction management team is to facilitate communication between all the concerned parties, "The purpose of Construction Management is to ensure that a project is constructed safely; completed in a timely manner, within budget, meeting the requirements of the project drawings, project specifications, right of way line lists and in compliance with all Federal, state and local laws, regulations, permits and codes" [8].

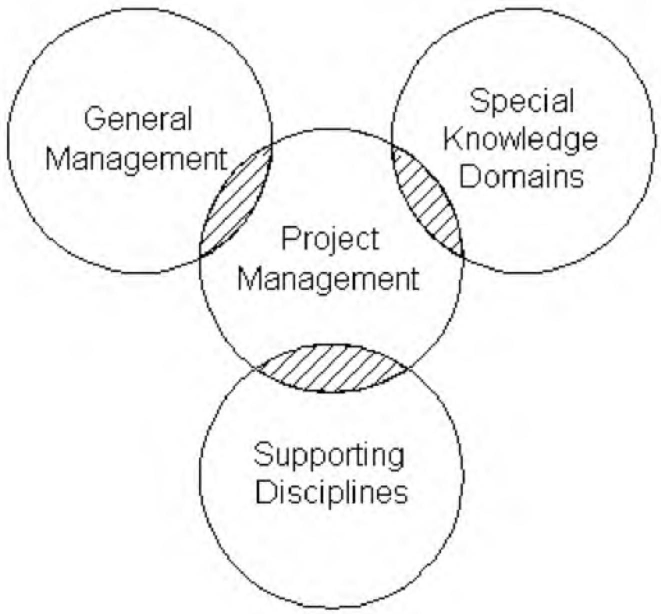


Figure 1.3: Management Diagram: Representation of different aspects of project management [9].

Construction Management teams are often known as Project Management teams. Figure 1 illustrates how the management team interacts with the other major partners in the project. The general management is the owner/ client, the special knowledge domains are the engineers and designers on the project, and the supporting disciplines are the contractors building the project. The difficulty in this structure is defining who is responsible for making particular decisions. The owner will not want to be bothered with questions on every detail of the project, like if 19mm bolt or " bolt should be used to anchor a plate to the floor of the pump house:

> It is critical that you establish a clear chain of communication and command for the input and distribution of information. All requests for information, change order requests, and directives to and from the Client should be introduced in writing and addressed through proper channels to ensure issues are responded to by the right party without delaying progress, and captured and documented for the project [10].

In order to facilitate the needs of each party there will often be specialists in the construction management office that deal with the technical details and filling out of forms for permits. The Project Management team is often also responsible for financial reporting both to the owner and to any governing bodies that require that information. During the construction process there will inevitably be obstacles that must be overcome that were not planned or designed for. These obstacles may or may not need approval from the owner/client, but will almost always need to be addressed by a member of the engineering/design team, if for nothing else than for a surveyor to make a note of the change for the as-built drawings.

The Construction Management team has a great responsibility, if they do their job properly then the project move along in a timely manner without overspending. If they do poorly they could cost the client billions of dollars in construction costs, environmental cleanup, and engineering fees. Communication between client, contractor, engineer, and project management is of utmost importance, and as long as the professionals involved have the experience, candor, and knowledge necessary to do their jobs and respect the efforts of the others, then communication can be effective.

The Uinta Express Pipeline Company is a subsidiary of Tesoro Refining and Marketing LLC; this makes it seem obvious that the pipeline company will act as the construction manager for this particular pipeline. They will have the responsibility of moving the project through all steps of construction from the EIS to post-construction site restoration.

1.4 Contract Solicitation

There are three types of solicitations generally used throughout the construction industry today: Invitation for Bid, Request for Proposals, and Competitive Negotiation. Each method is slightly different with the same end goal, for the builder to find a contractor that can do the work in a timely fashion for a reasonable price. Some methods have the details of the projects spelled out very plainly while other ask for the potential contractors so explain how they would complete the project. Every company that puts a project out to bid has their own set of values and directives for selecting the winning bidder.

The Invitation for Bid is the simplest method and is used when there are few possibilities in the methods that are typically used for a particular job. Bidders are told what, how, when, and where the project is to be done. The lowest bidder who is deemed to be responsible and reliable is awarded the contract. A Request for Proposal may have a very detailed statement of work, or it may only state an end goal and objectives. In these proposals the client is seeking a contractor that can come up with their own methods of accomplishing the goal. The state of California splits RFPs into two groups summarized in Table 1. The contractor that submits the highest scoring proposal for the lowest cost is awarded the contract. The third type of solicitation, competitive negotiation, is used when the scope of the project is more complex, and in person meetings between the client and bidders make it more feasible for the project to be successful. The client will put out a statement of work to which bidders respond with plans and ideas of how the project can be completed, this step is the same as in a RFP. The highest scoring bidders are then contacted by the client and negotiations on standards of construction and fees are started, the most reasonable contract that meets the needs of the client is then selected.

1.5 Site Inspections

The site where any construction takes place is the most important decision that there is in the design process. Whether it is for a pipeline or for a more picturesque venture such as a writing hut, “The testimony of our senses seems adamant that space is full of interruptions and breaks and places qualitatively different one from another.” [11]. This definition applies quite well to homes, cottages, cabins, and schools but not very well to pipelines. The selection of the site of a pipeline depends more on economics and other quantitative values rather than on the qualitative. A preconstruction site inspection occurs along the potential routes of a pipeline, this is the beginning of the environmental impact study. Site inspections continue throughout the construction process, and then a year or two after construction is complete a final site inspection is necessary to ascertain how well the site has been restored to acceptable levels of environmental quality.

Table 1.1: RFP Definitions: Primary and Secondary RFP Definitions.

	Primary	Secondary
Services Required	Services are complex, but not uncommon or unique.	Services are complex, uncommon, or unique.
Scope of Work	Fairly well defined services or functions to be performed and the required time frames.	Less precisely defined and may contain only needs, goals, or objectives that must be met.
Performance	Requires varying methods or approaches, but not innovative or creative.	Requires unusual, creative techniques, methods, and approaches.
Evaluation	Proposals are reviewed, evaluated, and scored for compliance with format, content and qualification requirements; cost proposals are not scored.	Proposals are reviewed, evaluated, and scored; oral interviews may be conducted; passing scores set for finalists; and the cost proposal is scored.
Contract Award	Lowest cost, qualified proposal.	Highest scored, qualified proposal.

The initial site inspection consists of survey teams, aerial photographs, experienced contractors, and engineers. These people gather as much information about the site as they can, from GPS points and land contours to soil samples all to aid in the design of the pipeline. This inspection also provides a lot of information to the people doing the EIS, who in turn can determine if the proposed site is acceptable to the construction project. During construction site inspections become construction inspections. Inspectors work closely with contractors and laborers to ensure that the pipeline is built to design specifications. The inspectors may take compaction readings during backfill, test welds on the pipe electronically, confirm proper installation of heating elements, observe trench bedding, or any number of technical operations, which require exact specifications.

Part of the pipeline construction is landscape restoration, the construction process can be very damaging to the native ecosystem and that damage must be mitigated in order for most landowners and government agencies to allow the pipeline to be constructed through their property. At a predetermined time after the contractor has done his part in the remediation of the landscape a group of inspectors will visit the site to analyze how well the site is returning to the state it was in before the pipeline was put in. It will never be quite the same, often trees are kept back from the pipe centerline to allow for emergency repair crews to quickly get to remote portions of the pipe that may come in need of immediate repair in the future. But even though access is maintained, it is possible for the landscape to be healthy and supportive to the flora and fauna that is native to the area. William's policy is to clean up and restore the work area as soon as possible. After the pipeline is backfilled and tested, disturbed areas are restored as close as possible to their original contours. Restoration measures are maintained until the area is restored, as closely as possible, to its original condition [13].

Site inspections are necessary to maintain a high level of quality control in the construction industry. Whether it be pre-construction surveying or post construction restoration analysis these inspections help to keep contractors doing the jobs that they are hired to do, and help to keep the land a viable resource for generations to come.

1.6 Construction Project Planning and Scheduling

Before construction can begin on a project, it takes months or even years to prepare the administrative and civil paperwork, conduct meetings with the federal, state, and city officials to get the pipeline regulatory and environmental, civil, and design permits, plan and schedule, get construction bids and contract awards, and finally give a notice to proceed (NTP). These are just some of the components and documents required for any civil infrastructure project.

Ms. Laynee Jones is the project manager overseeing the Mountain Accord project and Mr. Mike Grodner is a service consultant on the project. Both Jones and Grodner discussed the timeline of construction projects during a presentation at the University of Utah during

October, 2014. Research prior to the commencement of construction on a project is perhaps the most important phase of the entire project. In other words, preliminary research determines the planning sequences and answers what, how, who of events [14].

Both Ms. Jones and Mr. Grodner say that a project begins on a political level. For instance, a politician will tell the public and their constituents: "We need better a better transportation system." Once support for a project is gained, the following process is followed.

Figure 1.4: Construction Planning: Steps for planning construction projects.

After all of the administrative and legal documents and permits are issued, the pipeline construction sequence roughly follows the outline shown in the figure below in accordance with the Pipeline Planning and Construction Field Manual (PPCF).

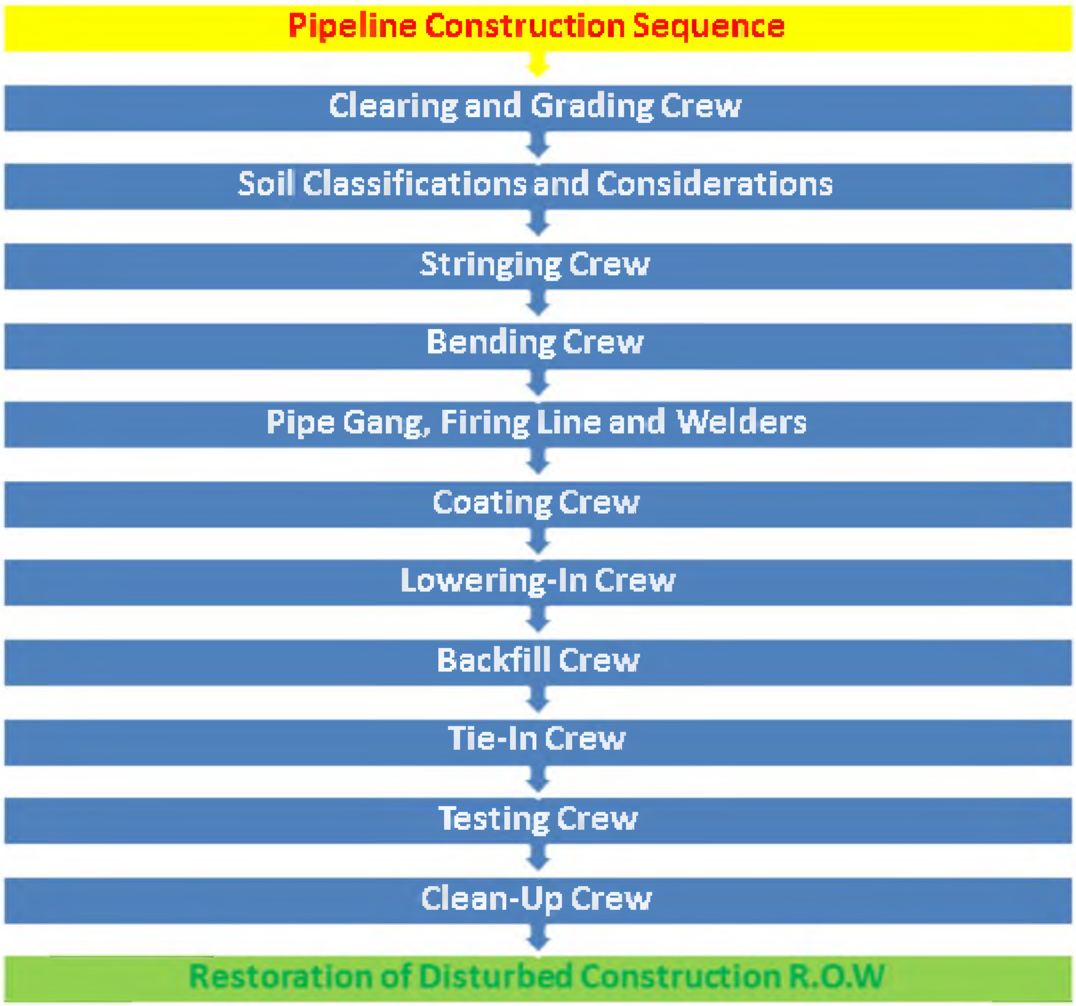


Figure 1.5: Pipeline Construction Sequence: Typical outline of pipeline construction.

Each phase represented in the preceding figure is detailed and complex in its own right, but, for the scope of this report, the placeholders representing each respective phase will suffice. A sample work schedule for one segment of a similar pipeline project is illustrated in the following table.

Table 1.2: Construction Project Schedule: Sample schedule of a pipeline segment.

Uinta Express Pipeline Construction Project Schedule													
S= Start of Activity										F= Activity Finishes			
Start Date: 06/16/2016										Completion Date: 09/16/2016			
		.=work in progress				.=Construction warnings							
		.= Landscaping											
No	Work Description	June				July				August			
	General Items	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4
1	Mobilization					F							
2	Cleaning and site preparation	S					F		S				
3	Soil Classify& Consider												
4	Clearing and Gradation	S				F						F	
5	Excavate			S									
6	Gradation, compaction												
7	Slabs/Foundations								S				
8	Stinging, bending Crew												
9	Pipe Gang, FireLine&Welders			S							F		
10	Coating Crew,												
11	Lowering-in Crew								S				
12	Backfill Crew	S											F
13	Testing Crew						F						

14	Restoration of Disturbed Construction R.O.W									S			
15	CleanUp/ punchlist/ Demobilize									S			F
16	Turnover												

Table 1.2 shows the sequence of events that take place during installation of a specified length of pipe. Areas of concern in each phase, such as meetings, deadlines, and milestones are highlighted in the construction project schedule. Project progress and payment milestones can take place at the beginning, during, or at the end of the phase. For example, payments may be made after 40% of phase is completed.

The schedule is the most important document in planning and communication guidance for all the teams involved. Scheduling terms have a definable start and end. Work packages (i.e. mechanical activities) for an area, need to be clearly defined from start to finish. Different methods of planning include standard logic, critical path analysis, and free float analysis. If someone delays work for one day what can happen? Do the constructions managers extend the completion date or should a schedule be revised and or manpower increase is necessitated? These scenarios need to be accounted for during the planning phase [15].

In the article "Shrinking Oil Supplies Put Alaskan Pipeline at Risk," Russel Gold states that "Seventy thousand workers took more than three years to build the conduit, commonly known as TAPS, which ended up costing nearly $8 billion, plus interest, in 1970s dollars" [16] (referring to the Alaskan Pipeline). The size and the scope of Uinta Express Pipeline roughly compares to the Alaskan Pipeline. So, it would not be unreasonable to assume that the time and budgets of the two projects would also be comparable. Although Tesoro hopes the line will be built and operating as early as 2016, they must wait for the U.S. Forest Service to issue its final Record of Decision before plans can be finalized [1].

When it comes to the scheduling and control of a pipeline construction project, the timeline for construction metaphorically parallels the pipeline, itself. Project managers ensure that the construction runs according to the plan and avoids any unnecessary conflicts. This prevents interruptions to work and makes it possible for the project to be completed as planned. The planning process determines the what, how, and who of events. The schedule is the reflection of the finalized plan and the statement of work (SOW) - another important document governing project milestones and the project's education plan. The SOW defines a linear path for construction process to follow. A typical SOW, for instance, describes processes in way that says: "Complete foundation excavation, and then move to compacting, etc." [15].

As reported by the Uinta Express Pipeline Company, the following figure shows that "The timeline for the final Environmental Impact Statement and Draft Record of Decision [ROD] will be released in December 2015 followed by a 45-day objection period. The U.S. Forest Service will issue its final Record of Decision once this period is complete" [17].

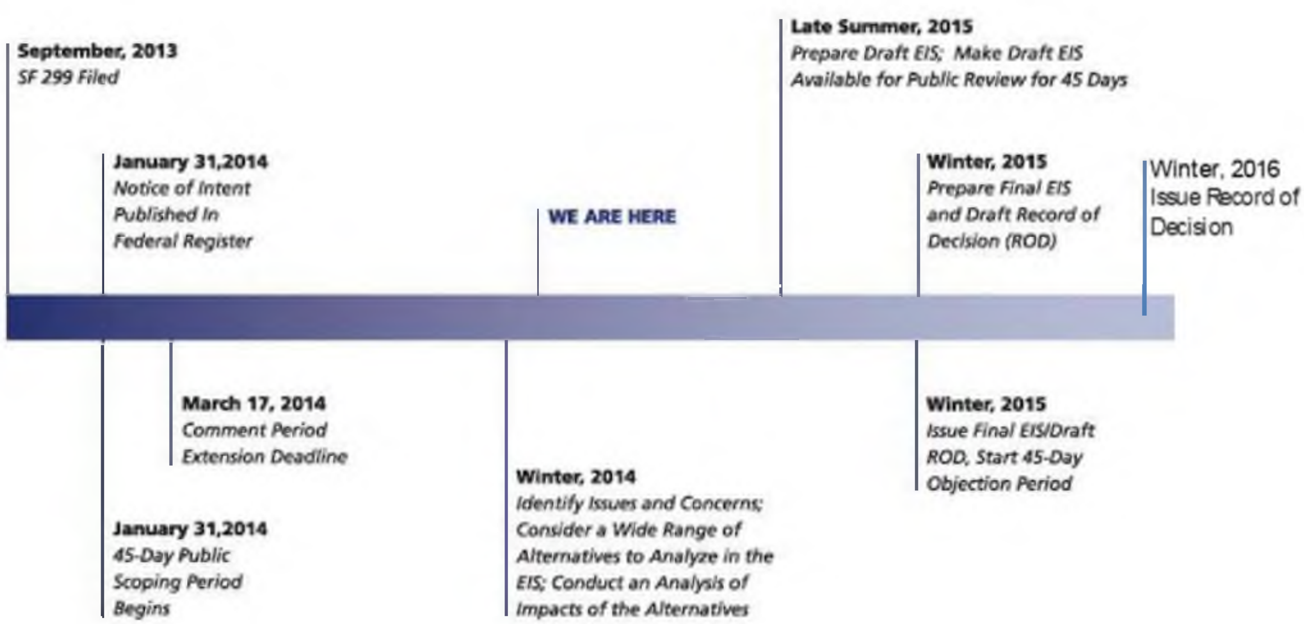


Figure 1.6: EIS/ROD Schedule: Timeline for the final EIS and ROD of the UEP [17].

Figure 1.6 gives an overview of project milestones. This will help all involved parties plan and coordinate accordingly. Such master plans and projections prevent any possible conflicts of time or interest amongst all involved contractors.

Table 1.3: Time Study of Eight Process Engineers.

Activity of Engineers	Percentage of Time
Consulting outside of scheduled jobs	4.4
Section supervision duties	4.7
Meetings related to scheduled jobs	13.7
Discussion with vendors	2.6
Special technical assignments	2.4
Communications within section	5.9
Process design calculations (original)	51.0
Process design calculations (checking)	3.7
Equipment Schedules, line schedules, and so on	3.1
Flowsheet development, checking, revising (no drafting)	2.5
Coffee breaks, miscellaneous activity	6.0
Total	100.0

Table 1.3 gives an example of how industry process engineer's time is spent. This Table shows a time study breakdown of eight process engineers with a minimum of five years of experience. The table illustrates that over 50% of the engineers' time is spent working on things other than designs and calculations. A proper planning, scheduling and communication plan can help engineers to allocate and use their time efficiently.

1.7 Conclusion

In order to tackle the challenge of transporting the ever increasing amount of high-paraffin waxy crude oil produced in the Uinta Basin to refineries in Salt Lake City, it is clear that the construction new pipeline is the best option.

The land acquisition aspect of the pipeline project makes the proposed Northern route the most attractive option. When compared to the alternative routes, the Northern route crosses through less National Forest land, and it does not intersect a State Wildlife Reserve. Crossing Forest Service land requires special permitting which calls for an in-depth examination of the environmental impact in order to generate an Environmental Impact Statement. In addition to the EIS, the successful completion of the project will require the acquisition of private land. The private land falls under the jurisdiction of eminent domain, so all land required for the pipeline will be able to be obtained.

After the site-selection process is complete, the route is clearly defined, and the pipeline design is finalized, the bid process can begin. Once a bid is awarded, construction can begin. During the construction process site inspections are scheduled through the construction management team to ensure that all portions of the pipeline are built to design specifications. The construction management team will keep the contractor and owner up to date on inspectors' findings. If any changes need to be made, the contractor will work in coordination with the inspector and engineers to make the desired modifications.

The planning and scheduling of the construction process will serve to keep the involved contractors on schedule so that the project can be accomplished on time and within budget. Proper planning and scheduling will help contractors to efficiently manage their daily operations and will mitigate less than desirable performance from their crews while keeping the best interest of all involved parties. Complete master plans and projections ensure that there will not be any time or interest conflicts between the different contractors. If all construction phases are completed according to the specified schedule and without any major deviation from the original plans, the construction could be completed within three years. If the US Forest Service Issue Record of Decision is completed by winter of 2016, based upon currently available information, the 135 mile long pipeline connecting the Uinta Basin to oil refineries in Salt Lake City could be in full service by 2020.

1.8 References

[1] N. Snow. (1994, September 1). Utah's crude transportation options include Uinta Express project [Online]. Available: http://www.ogj.com/articles/print/volume-112/issue-9/general-interest/utah-s-crude-transportation-options-include-uinta-express-project.html.

[2] D. C. Whittekiend. (2014, January 22). Invitation to comment on the proposed action for the Uinta Express Pipeline [Online]. Available: http://www.uintaexpresspipeline.com/images/documents/uep_scopingletter.pdf.

[3] Extension: Utah State University. (2009). Land Ownership of Utah [Online]. Available: http://extension.usu.edu/utahrangelands/images/uploads/web-images/land_ownership.jpg.

[4] Summit County, Utah. (2014). Uinta Express Pipeline, [Online]. Available: http://www.co.summit.ut.us/564/Uinta-Express-Pipeline.

[5] US Legal, Inc. (2014). Eminent Domain, [Online]. Available: http://eminentdomain.uslegal.com.

[6] Utah State Legislature. (2014). Title 78B Chapter 6 Section 501, [Online]. Available: http://le.utah.gov/~code/TITLE78B/htm/78B06_050100.htm.

[7] J. Ward. (2014). Oil Pipeline, [Online]. Available: http://www.arcgis.com/home/webmap/viewer.html?webmap=0e6dff57ea0e46d3a15ed6bc903a726b&extent=-112.0089,40.0359,-109.9805,40.9632.

[8] Orleans Holding Company. (2013). Pipeline Construction Management, [Online]. Available: http://orleansholdingco.com/services.

[9] C. Hendrickson, "Organizing For Project Management," in Project Management for Construction, 2nd ed. 2008.

[10] J. Wolf. (2011, June 20). The Importance of Communication During a Construction Project, [Online]. Available: http://www.stonemarkcm.com/design-construction-management-blog/2011/06/20/stonemark-construction-management-blog-the-importance-of-communication-during-a-construction-project.

[11] M. Pollan, "The Site," in A Place of My Own: The Architecture of Daydreams, 2nd ed. New York: Penguin Books, 2008, ch. 2, p. 52.

[12] CalPERS. (2014). Contract Solicitation Methods, [Online]. Available: https://www.calpers.ca.gov/index.jsp?bc=/business/how-to/contractmethods.xml.

[13] Williams Companies, Inc. (2014). Pipeline Construction, [Online]. Available: http://co.williams.com/williams/operations/gas-pipeline/pipeline-construction/.

[14] L. Jones and M. Grodner, seminar presentation, Oct. 2014.

[15] Construction-projects.com. (2014). [Online]. Available: http://www.construction-projects.com.

[16] R. Gold. (2011). Shrinking Oil Supplies Put Alaskan Pipeline at Risk, [Online]. Available: http://www.sltrib.com/sltrib/news/57490216-78/oil-pipeline-uinta-crude.html.csp.

[17] Uinta Express Pipeline Company, LLC. (2014). Home, [Online]. Available: http://uintaexpresspipeline.com/.

[18] A. K. Coker, "Time Planning and Scheduling," in Ludwig's Applied Process Design for Chemical Petrochemical Plants, 4th ed. Houston, TX: Gulf, 2007, ch. 1.19.

Chapter 2

Economic Impact and Policy

Abstract

This chapter analyzes the economic impact the proposed Uinta Express pipeline will have on Utah's economy. The economic impacts include tax revenues, gas prices, government policy, and job creations, as well as the impact the OPEC nations might have on the United States and Utah's oil infrastructure. The production of waxy crude in the Uinta Basin continues to increase and without the proper infrastructure to transport the waxy crude 29 billion dollars will be lost in the next few decades.

Large oil companies such as Chevron, Tesoro and HollyFrontier have pledged over 500 million dollars to improve, and prepare oil refineries in Salt Lake City to meet the increased amount of oil if the pipeline is constructed. With the new pipeline, the HollyFrontier Company will double its contributions to Utah's gross domestic product to nearly 801 million dollars per year. In addition to increased revenue the price of gasoline and petroleum based products will decrease.

In comparison to other proposed pipelines such as the Keystone XL and the operational UNEV Pipeline assumptions were made in regards to the amount of personnel needed to construct the pipelines. 100-150 workers would be needed to construct the pipeline. After completion, only 5-10 permanent jobs would be available. Furthermore, after completion 250 tanker truck drivers would be left unemployed. The amount of jobs created and the amount of jobs lost do not offset each other. In a region were a large amount of the population is employed directly and indirectly by the oil companies, this job loss will impact the region negatively.

The OPEC nations have decided to maintain production at steady level to try and drive smaller U.S. companies out of business. Small companies such as the Uinta Express Pipeline will not be able compete with the low oil prices that the OPEC nations can provide. The issue of whether to build the pipeline arises, as it might not be profitable to invest in if the OPEC nations continue to drive oil prices down. However, analyst agree that the price per barrel will go back to profitable prices and Utah will have the necessary infrastructure to meet the demand of high oil production if the pipeline is built.

2.1 Introduction

This chapter analyzes the economic impacts and policy regarding the proposed Uinta Express Pipeline (UEP). The Uinta Basin covers an area of approximately 15,000 square miles and the total in place resource for the basin is approximately 1.32 trillion barrels [1]. This number however is the total estimated amount of oil deposits and not the recoverable amount of crude oil available. Regardless there is great potential for profit and economic growth for Utah and the surrounding States. The proposed UEP will allow the recovered waxy crude oil to be carried from the basin to oil refineries in and around the Salt Lake valley. This report will make several assumptions when estimating economic impact and will try to account for as many factors influencing the economy as possible. It will also go into an in depth discussion on the necessary policy to construct this pipeline.

2.1.1 Objectives and Methodological Approach

The main objective of this report is to examine the economic impact and policies of the proposed UEP. More specifically, these impacts include:

1. Economic output of the pipeline measured by the value added to the states gross domestic product
2. Value of production and refinement in an area
3. State and local tax revenues generated
4. Jobs created and sustained through this pipeline.
5. Effect on gas prices and other petroleum products

This will be done by developing a criteria for analysis by which a region will be economically affected by the addition of a pipeline, and then use this criteria, to compare other similar pipeline projects and their economic impact. Finally using the criteria to make estimations of the impact the UEP will have on Utah's economy. The policies needed to construct a pipeline will be researched and the current status of the UEP will be pinpointed. Then the next step in the design process will be outlined.

2.1.2 Analysis Assumptions

Due to the fact that the pipeline is in the early stages of design it was necessary to make certain assumptions in order to accurately make an estimation. We made assumptions when comparing the UEP to other pipelines due to differences between them. While we tried to find comparable pipelines with respect to their dimensions, economic impact, and policy very few of them were exactly alike. Because of this percent reductions in data found for other pipelines was necessary. Our numbers we estimated are only rough estimates and will most likely change.

2.1.3 Criteria for Analysis and Comparison

There are far more effects to the economy than can be analyzed and so this criteria will be generic and broad but will be sufficient for the purposes of this chapter. The points of analysis and comparison are as follows:

- Direct Economic Impact: These are economic activities directly associated and generated by the pipeline and directly include companies, firms, and contractors associated with the construction and operation of the pipeline. These activities include:
  1. Jobs created and sustained from the construction and maintenance of the pipeline
  2. Revenue generated directly from the pipeline

- Indirect Economic Impact: These are economic activities that are a result from the direct activities or not directly influenced by the pipeline. These activities include:
  1. The processing of the crude oil if not done by the same company
  2. Reduction/Increase of products made as well as price from the crude oil; such as local gasoline prices
  3. Other business generated or attracted from the new pipeline

- Policy: Activities performed that contribute to or allow the pipeline to legally be constructed. These activities include:
  1. Permits and Ordinances
  2. Environmental Impact Statement
  3. Land rights and usage

With comparison criteria outlined, comparable pipeline projects can help estimate the economic impact of the UEP. There are approximately 61,000 miles of crude oil pipeline in the United States, which does not include 63,500 miles of refined petroleum pipelines, or the 62,700 miles of natural gas liquid pipelines [2].

Table 2.1: Comparative Pipelines: Pipelines used in comparison [3] [4] [5].

Pipeline Name	Location	Length (miles)	Diameter (inches)	Capacity (bbl.)
Keystone XL	Hardisty, Canada to Steele City, Nebraska	1,179	36	830,000
UNEV	Salt Lake City, Utah to Las Vegas, Nevada	425	12	60,000
Longhorn	Crane, Texas to Houston, Texas	525	12	225,000

2.2 Uinta Express Pipeline—Generation of Revenue

The economic impact of the Uinta Express Pipeline (UEP) is vast and can contribute billions of dollars to the economy in Utah and other states. Specifically, UEP can provide large amounts of revenue for local areas in the Salt Lake Valley as well as other counties the pipeline will be constructed on as property tax revenue. This portion of the report explores areas on what economic impacts this project could have in Utah.

2.2.1 Predictions in Economic Impact of Construction

Calculating the construction economic impact of such a large project is difficult to do, but looking at past pipeline construction and studies on other proposed pipelines gives insight on what the UEP economic impacts might be. Therefore, a look at several pipelines would be appropriate to compare with the proposed UEP. For example, the Keystone-XL Pipeline (KXP) would an adequate comparison because the area the pipeline crosses through states that are close enough geographically that they can be compared economically, culturally, and politically, as can be noted on Figure 2.1.

The economic impact during the construction phase can be divided into “three distinct components: direct, indirect, and induced” [6]. Direct economic activity is associated with construction of the actual pipeline. This “includes all jobs and earnings at firms that are awarded contracts for goods and services, including construction," directly by the Project [6]. Indirect economic activity "includes all goods and services purchased by these construction contractors in the conduct of their services to the proposed Project. Examples of these types of activities related to pipeline construction include the goods and services purchased to produce inputs such as concrete, fuel, surveying, welding materials, and earth-moving equipment" [6]. Induced economic activity "includes the spending of earnings received by employees working for either the construction contractor or for any supplier of goods and services required in the construction process. Examples of induced activities include: Final Supplemental Environmental Impact Statement, spending by access road construction crews, welders, employees of pipe manufacturers, and ranchers providing beef for restaurants and construction camps" [6].

According to a report on the proposed KXP, "during construction, proposed project spending would support approximately 42,100 jobs (direct, indirect, and induced), and approximately $2 billion in earnings throughout the United States. Although the size of KXP (1,179 miles long) is about 6 times the size of UEP (135 miles long), the economic impacts will be less than that fraction and can contribute to about half of those earnings. Some of the direct economic activity could be generated by the

Figure 2.1: Keystone XL Pipeline Routes: Geographic proximity to Utah [6].

materials, contracts, and support purchased in the United States for UEP. Such is the case for KXP, which would amount to "approximately $5.3 billion. Another $233 million would be spent on construction camps for workers in remote locations" throughout the several states [6]. UEP could contribute millions of dollars in the construction phase as a direct economic input of revenue to several counties. Calculating the cost per mile of pipeline of the KXP and directly proportioning that cost per mile of pipeline on the UEP, the cost of the UEP will be around $609 million, as seen in Table 2.2.

Table 2.2: KXP vs. UEP: Estimated cost of UEP from KXP estimates [6].

	KXP	UEP
Length (miles)	1,179	135
Ratio (mile/mile)	8.7	8.7
Cost Per Mile ($ in Millions)	$4.50	$4.50
Total Cost ($ in Millions)	$5,300	$606.9

2.2.2 Contribution to Utah's GDP

Construction of UEP can also contribute to a large increase in Utah's annual gross domestic product (GDP). Evaluated at a national level, KXP would "contribute approximately $3.4 billion (or 0.02 percent) to the United States GDP. The proposed Project would generate approximately 50 jobs during operations" [6]. The generation of revenue for UEP will probably not contribute as much, but the operations of such pipeline could be similar. In fact, one study suggests that "crude produced there [Uinta Basin] is higher quality and comes from shallower wells than many parts of the US, Pope said, adding that yearly production could reach 20 million bbl. by 2022 if the necessary transportation is available. If it isn't, he said, more than $29 billion of production could be lost by 2028" [7].

2.2.3 Pledged Investments of Oil Companies

For example, HollyFrontier Corporation estimates it "will pay $64 million in state tax revenue, up from $32 million, and contribute $801 million to Utah's gross state product, nearly double the current total" [8]. They expect these numbers to only improve with the second phase expansion of the UEP, which is expected to be completed after 2016. The refinery manager for HollyFrontier, Lynn Keddington, stated that "the expansion allows us to take advantage of Utah crude, creating more Utah jobs and state revenue — when the alternative is to buy Canadian crude with none of those advantages" [8].

When UEP is completed, the "refineries will take 99,000 barrels of Utah crude a day—up from 20,000 barrels six years ago" [8]. It is important to note that companies like HollyFrontier, Tesoro, and Chevron have already made projections on further investments in current refineries after the completion of UEP. For example, "HollyFrontier will invest $225 million during the next four years to increase production by 45 percent. San Antonio-based Tesoro Corp. expects to invest $180 million to increase processing capacity by 7 percent, and Chevron, based in California, has said it plans to spend $83 million upgrades to its Salt Lake refinery" [8]. Figure 2.2 shows investments pledged by major oil companies into oil refinery infrastructure.

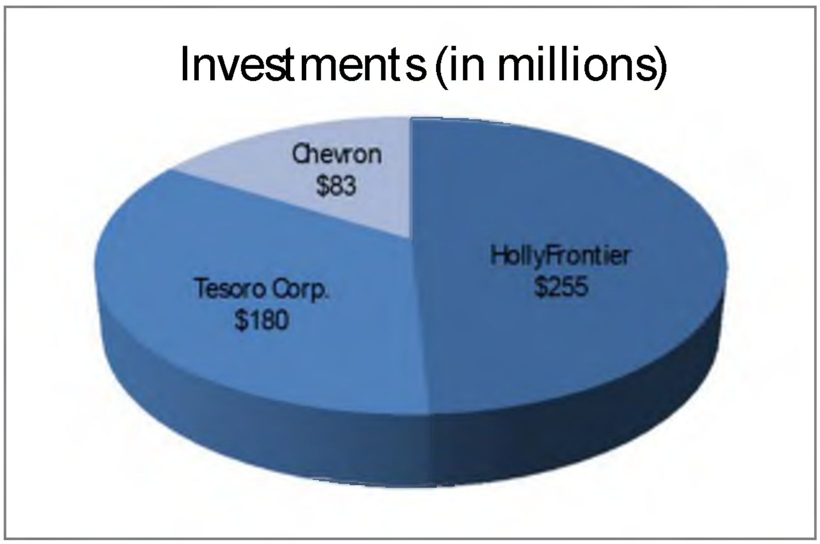


Figure 2.2: Investments of Oil Companies: Investment (in millions) into Salt Lake's Oil Refineries [8].

Other expansion agreements have been signed with these large companies. HollyFrontier signed a "10-year agreement with Newfield Exploration Co. to supply

20,000 barrels per day of Utah crude produced from the oil company's Uinta Basin properties. Tesoro signed a similar supply agreement with Texas-based Newfield" [8]. With some companies like Newfield planning to invest over $500 million in improvements for their refineries, the economic impacts of these investments could have significant effects.

2.2.4 Property Tax Revenues

Additionally, the property tax generated for some counties could amount to large amount of revenue. UEP will cross through Salt Lake, Davis, Morgan, Summit, Wasatch, and Dushesne counties. In the case of the KXP, the "property tax revenue during operations would be substantial for many counties, with an increase of 10 percent or more in 17 of the 27 counties with proposed Project facilities" [6]. As a large part of the UEP will cross Utah counties, a large portion of property tax revenue will go to inner state counties that can help with infrastructure development, school funds, etc. While the revenue might not be much for counties like Salt Lake and Davis, the increase in revenue could be significant for the other counties, particularly Duchesne County where a large part of the pipeline will cross.

2.3 Analysis of Gas Prices and Other Petroleum Products

Crude oil like the waxy crude oil from the Uinta Basin is used to make a wide variety of products. One 42 gallon barrel of oil creates 19.4 gallons of gasoline [9]. The rest is used for other products such as solvents, shampoo, dentures, diesel fuel, and motor oil to just name a few. There are thousands of products that use petroleum and therefor it is an essential commodity in today's world. The Uinta Express pipeline would increase the amount of crude oil shipped to oil refineries in Salt Lake. This increased product effects the cost of these products and their distribution. The main focus of this section is its effect on local gas prices. This will be accomplished by looking at the Longhorn crude oil pipeline in western Texas. This pipeline was constructed in 1998 and it is therefore possible to analyze the effects it had on gas prices and the petroleum market in the beginning of the 21st century.

2.3.1 Longhorn Pipeline Comparison

The Longhorn pipeline is 12 inches in diameter and spans 525 miles starting in Crane, Texas and ending in Houston, Texas. The pipeline is owned and operated by Magellan Midstream Partners. It is used to transport crude oil drilled from the Permian Basin. This pipeline is also be a common carrier line allowing multiple refineries access to its transportation capabilities. Currently this pipeline has a capacity of 225,000 barrels per day (bpd). An expansion is under consideration that would add 50,000 bpd capacity that is currently at 275,000 bpd [5]. Although the length and capacity of this pipeline are larger than UEP, it is a good economic example during the oil boom in Texas.

In a report created by the EPA, the impact of the Longhorn pipeline on Texas and its surrounding areas is analyzed. The important factors explaining the current retail gasoline market are explained and provide a basis for analysis, as listed below:

- Proximity of supply—distance from the refineries supplying the local market, including proximity of refineries to crude oil supplies, shipping logistics, and pipeline or waterborne, from refinery to market.
- Cost of supply—crude oil, refinery operation, and transportation.
- Supply/demand balance—some regions are typically in excess or short supply, while others may vary seasonally, or when supply interruptions (such as refinery shutdowns) occur.
- Competitive environment—including the number of suppliers, and the degree of local market dominance by one or a few, as well as diversity of supply sources and barriers to entry.
- Local demographics—such as population density, per-capita income, station density, number of vehicles, etc.
- Operating costs—station rents, local wage rates, tax burden, etc.
- Taxes—per-gallon, e.g. excise, percentage, and sales taxes,
- Environmental programs—including oxygenated, reformulated, and low-volatility gasoline, and restrictions on transportation or storage [5].

The analysis of the change in gasoline prices is quite complicated. The EPA report goes into extensive detail and gives various statistics. According to the analysis the Longhorn pipeline the cities and areas of El Paso and Houston had gas prices 18-25 cents lower than other cities in Texas [5]. While this report is good for a basis of analysis it was created in January of 2000 and the Persian Gulf War was greatly driving up oil costs worldwide. Also since 2000 Texas has an even bigger influence on domestic oil prices because of Hydraulic Fracturing and new technology.

2.3.2 Utah Gas Price Analysis

The US Energy Information Administration (EIA) has extensive data on the different energy types, production, and consumption statistics for the United States. According to the EIA website, Utah typically accounts for 1 in every 100 barrels of crude oil produced in the United States and 1 in every 5 barrels for the Rocky Mountain states [2]. Oil production has more than doubled from 2004 to 2013 and met nearly six-tenths of Utah's demand in 2012 [2]. Utah currently has 5 oil refineries which process crude oil brought in from pipelines from Utah, Wyoming, Colorado, and Canada. The refineries, which produce motor gasoline, diesel fuel, jet fuel, other fuel oils, and wax, represent more than one-fourth of the refining capacity in Petroleum Administration for the Rocky Mountain region. While refined petroleum products are piped in to Salt Lake City from Wyoming and Montana, Utah is also piping product out into markets in Idaho, eastern Oregon, and eastern Washington State [2].

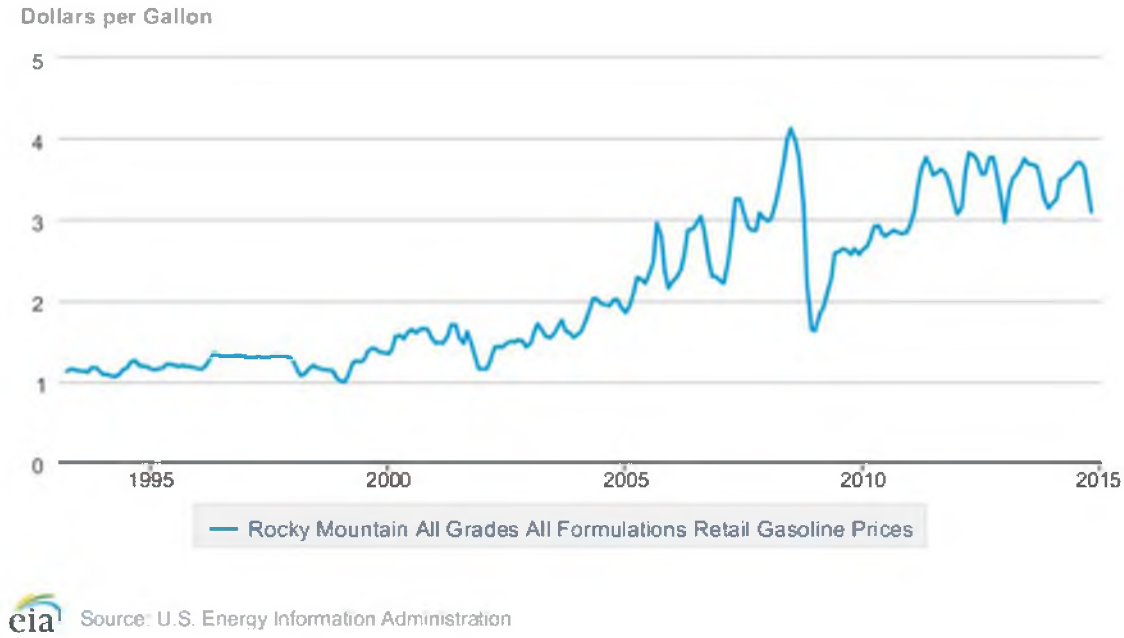


Figure 2.3: Rocky Mountain Retail Gasoline Prices: Retail gasoline prices [2].

Utah's petroleum consumption per capita is in the lower two-fifths nationally. More than four-fifths is consumed by the transportation sector [2]. Figure 2.4 shows the price breakdown of gasoline and diesel fuel, which can vary greatly depending on a variety of factors. Figure 2.4 illustrates that over half of the total price is dependent on the cost of crude oil and refinement; the rest of the cost goes into distribution and taxes. The addition of the UEP will greatly affect the cost of gasoline and diesel fuel because it will allow more local product to be transported to local refineries, which will drive down costs of domestic gas. This trend can be followed for other petroleum products as well. Figure 2.3 shows the retail gasoline prices for the Rocky Mountain region for the past 20 years. Gas prices have risen since 2002 and spiked drastically in 2008 due to the economic recession. Since then prices have stayed relatively consistent despite seasonal rises and falls. Currently, the price of gas hovers between 3 and 4 dollars/ gallon, due largely to the fact that the US and Utah are becoming more oil independent. The United States has a goal to be free from foreign oil dependency by 2020. From this graph we can predict that Utah's gas prices will continue to decrease with the construction of the UEP.

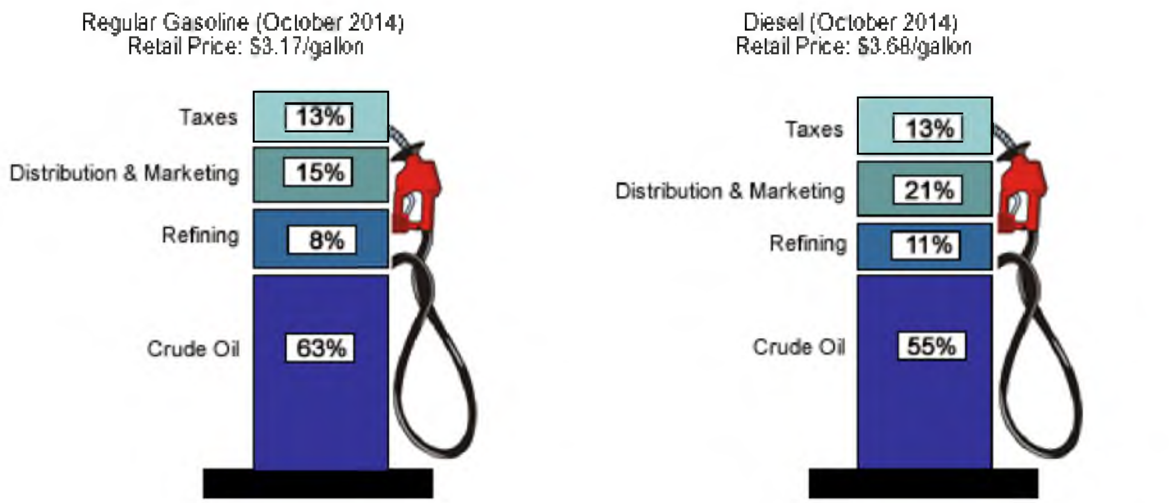


Figure 2.4: Fuel Price Breakdown: Percentages of total price breakdown.

2.3.3 Result of UEP on Gas Prices

The UEP is projected to have a capacity of 60,000 barrels per day (bbl.) [10]. Currently, the crude oil from the basin is transported by tanker truck. The refineries in Salt Lake City have a refining capacity of 65,000 bbl. and are planning to expand to nearly 100,000 bbl. in the coming years [10]. This pipeline will increase the total crude oil transported to local refineries. We can see from the cost breakdown of the price of gas that a large portion of the cost comes from refining and buying barrels. The addition of more oil in refineries will increase the amount of refined fuel and other petroleum products which in turn will drive the cost of our local gas down.

2.4 Discussion on Policy

UEP is still in the early stages of the design process. The pipeline has four proposed routes that will cross through several Utah counties. 15 of the proposed 135 mile pipeline will go through forest service lands. Not knowing the exact route makes it hard to determine the construction cost. There are countless aspects to consider and plan for in this project. The pipeline can be perfectly engineered and designed, and yet can still fail if the proper protocols and policy procedures are not followed. In order for the project to move forward several things need to happen. Permits need to be acquired, and environmental impact statement needs to be created, and the state and publics concerns need to be addressed.

2.4.1 Environmental Impact Statement

The National Environmental Policy ACT (NEPA) establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and provides a process for implementing these goals within the federal agencies. The act also establishes the Council on Environmental Quality (CEQ) [10]. The main purpose of this policy is to require that the federal government use all practical means to create and maintain conditions under which man and nature can exist in productive harmony. The NEPA process analyzes the environmental effects of the UEP on the three proposed routes and especially the 15 mile section going through Forest Service lands. Figure 2.5 is a map of the proposed routes. The Forest Service land is represented on the map as a tan color. This process consists of analyzing and investigating issues on the ground and finding possible alternatives. Then several surveys will be completed providing information of wildlife, soil, and cultural impacts to the area.

After the analysis an environmental impact statement (EIS) is issued. The public can contribute to the EIS by providing input on what should be considered and commenting on the findings of the EIS. Currently, Tesoro is working with different agencies to issue an EIS. Depending on the findings of the statement and the public's comments the pipeline may have to take an alternate route that does not go through the forest service's land or diverts around other environmental obstacles, which may cause the construction cost to raise and jeopardize the entire project.

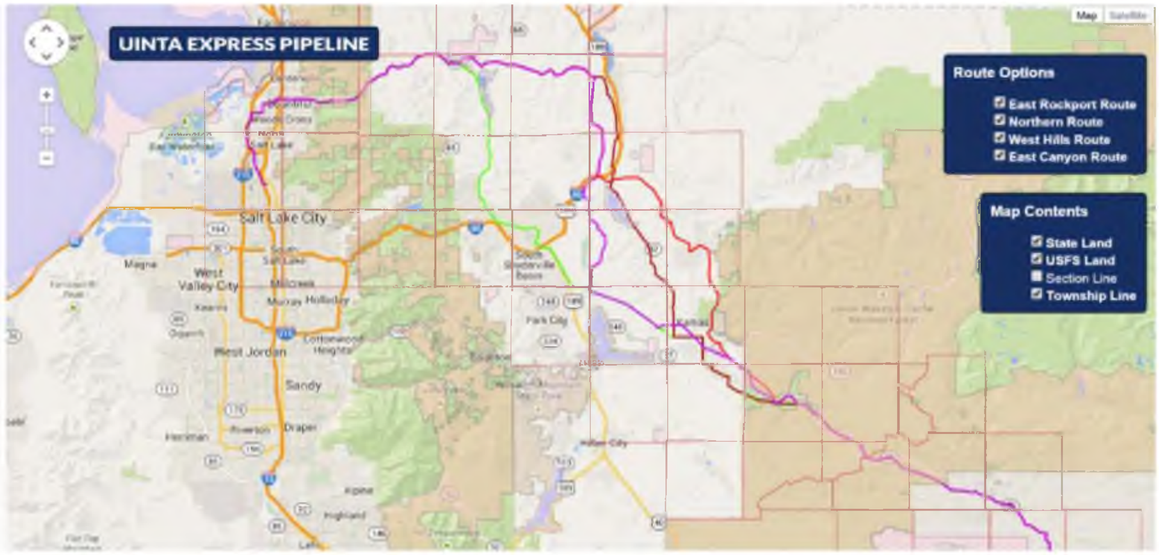


Figure 2.5: Uinta Express Pipeline Routes: Description of the proposed routes [10].

2.4.2 Permits and Ordinances

The UEP pipeline will potentially cross 7 counties. Figure 2.6 is a map of the different counties that the pipeline traverses. In addition to an EIS, several other permits are needed to build the pipeline through the different counties. Depending on what type of land the pipeline goes through determines what permits are needed. The UEP will be an intrastate pipeline meaning the entire pipeline will be constructed entirely within the state. Because of this the counties have the ability to secure permits and ordinances that effect the route and construction of the pipeline. While the County may influence the route of the pipeline, it cannot outright prohibit the pipeline's construction. Permits and ordinances that can be issued involve the engineering and construction aspect as well as the land use aspect.

The Engineering aspect includes ensuring that during the design and construction phase the workmanship and quality of work is not only up to code but of a sound and correct nature. This includes ensuring that construction crews do not cut corners and complete the construction process as designed. Ordinances also ensure that the infrastructure, such as roads will be put back correctly after construction. They allow the county to identify and approve the seed mix or mulch to prevent weed encroachment on top of the pipeline right of way. Lastly they allow the county to require as-build engineering drawings to ensure a satisfactory final product [12].

The land use aspect deals mainly with setbacks from structures, water sources, and essential public utilities. A setback is the distance the pipeline is from those essential structures and resources. In Summit County a permit was administered for where the pipeline traverses over unincorporated lands. This permit is called a Conditional Use Permit (CUP). The CUP prohibits Tesoro from building its pipeline

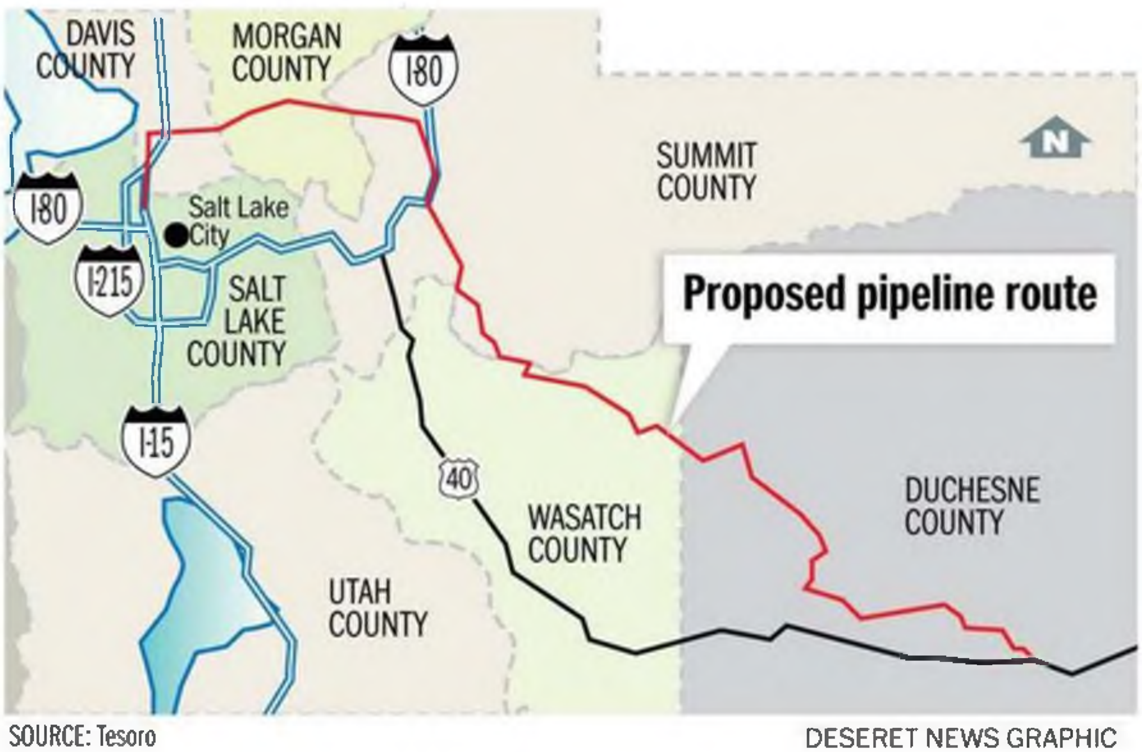


Figure 2.6: Uinta Express Pipeline Route: Different counties pipeline traverses [11].

within 500 feet of any structures, 2,500 feet from any water resource, and 2,500 feet from any essential public facilities or high consequence land uses (which are high density locations where evacuation would be problematic - schools, hospitals, etc.). The CUP requires that any stream or river crossing be accomplished by boring 10 feet under the water channel, providing a barrier between the pipeline and the water, and placing isolation valves on either side of the water resource to allow immediate shut off in the event of a breach in the pipeline [12]. However, the CUP is only valid for 180 days and therefore a more permanent permit will need to be considered. Permits like these will be enacted throughout the route of the pipeline.

2.4.3 Eminent Domain

The last issue of policy that is of drawing a lot of attention and concern from owners of private lands is eminent domain. Eminent domain is the legal ability of the government or its agent, in this case Tesoro cooperation to expropriate property for public use, with payment of compensation. Under title 78B chapter 6 section 501 letter d, it states under what circumstances this may be used stating "gas, oil or coal pipelines, tanks or reservoirs, including any subsurface stratum or formation in any land for the underground storage of natural gas, and in connection with that, any other interests in property which may be required to adequately examine, prepare, maintain, and operate underground natural gas storage facilities;" [13]. This is generating a lot of concern for property owners who don't want their land seized. Tesoro Vice President of Business Development Michael Gebhardt issued a statement saying "We're looking to maximize existing corridors, proximity to existing pipelines and minimizing impacts to communities." [14]. If Tesoro strives to avoid the use of eminent domain it will require a higher construction cost.

2.4.4 UEP's Next Step

The next step in the design process for the UEP is to determine what the actual route will be. This is dependent on the EIS, what permits are needed, the ordinances are required to follow, and what kind of land the pipeline will cross. All of these factors will determine the construction cost. After determining the actual total cost, Tesoro can then compare it with the cost of transporting the oil by tanker trucks. If the cost to build the pipeline is not cheaper than shipping by truck it is likely that it will not be built. This is an important step in the process and can determine the outcome of the entire project.

2.5 Analysis of Job Creation

There are many different aspects that need to be considered before constructing any type of infrastructure such as: the environmental and economic impact, government and public approval and the benefits and disadvantages of the construction project. The main focus of this report is the proposed construction of the Uinta Express Pipeline and its economic impact on the Salt Lake Valley and the state of Utah. More so the effect the pipeline will have on Utah's job market.

It is important to consider whether or not the pipeline will create jobs, if it does what kind of jobs will be available. Will the jobs be mainly labor intensive or are the jobs for more skilled workers? Due to the fact the more waxy crude will be transported through the pipeline than with the current method of tanker trucks, it is expected that hundreds of tanker trucker drivers will lose their jobs and it is still uncertain whether or not the creation of the jobs will offset the jobs that will be lost.

2.5.1 Temporary vs. Permanent Job Creation

During construction projects companies often times hire a large amounts of construction workers to complete a project. The amount of construction workers usually depends on the size as well as the type of project. For projects that are as large as the Keystone XL pipeline which goes from Canada to Nebraska and stretches a length of 1,179-miles a workforce of about 4000 construction workers will be required [15]. For a smaller project, such as the UNEV Pipeline which goes a distance of 425 miles from North Salt Lake to North Las Vegas as shown in figure 2.7. A workforce of 350-400 will be needed. The creation of these jobs is beneficial to the local economy and generates hundreds of thousands of dollars in payroll.

Figure 2.7: UNEV Pipeline: The length of the UNEV Pipeline as well as the thickness[16].

However, the majority of these jobs are temporary and only last until the project is completed. It was estimated that to complete the keystone XL pipeline, the construction workers would only be employed for about a year, after which the majority would be left unemployed [3].

The Keystone pipeline is not an isolated case where the majority of the jobs it claims to create are temporary; in actuality only a few permanent jobs would be created. Once the project is complete, the pipeline would only employee 35-50 permanent employees [3]. It is a large margin between employees who obtained permanent versus temporary employment. Similarly, during the construction of the UNEV Pipeline, hundreds of temporary employees were hired and once construction was complete they were left unemployed and only 18 permanent positions need to be filled [4]. Table 2.3 demonstrates that only 30% of temporary employees were local residents. A majority of the money earned by employees would not stay and benefit Utah or Nevada or the cities that the pipeline goes through. The UNEV pipeline does not make a significant impact in regards to employment opportunities for the residents of Salt Lake City, Las Vegas or the cities in between.

Table 2.3: Work Force Impacts: Assumptions for Determining Work Force Impacts to Local Areas [4].

Assumption	Result
Maximum workforce at any given time (proponent)	350-400 people
Workforce per full crew (all eight tasks) (proponent)	95
Assume maximum of two full crews per construction spread at any given time	190
Assume 30% local hires (proponent)	57
Non-local hires (190-57)	133
Assume approximately 20% of non-local hires bring their families, and each family adds three people (133 x 20% x 3)	80
Total non-local populations (non-local workforce plus families) (133+80)	213
Assume 30% of non-local workers would bring trailers for their housing (133 x 30%) (proponent)	40
Period of construction for project, 7-8 months (proponent)	210-240 days
Assume peak period of construction per spread is 2-3 months	60-90 days
Local spending by non-local workers and families	
Taxes collected on local spending by non-local workers and families	

The Uinta Express Pipeline is a proposed pipeline which is fairly smaller in size than that of the UNEV, stretching approximately 135 miles from Duchesne County all the way to Davis County and would have a capacity to transport 60,000 barrels of oil per day. Figure 2.8 details the path the pipeline is projected to follow. The Uinta Express Pipeline is still in the early stages of devolvement and no estimates on how many workers the pipeline would require have been made. However, in comparison with the UNEV pipeline conclusions can be made that the pipeline will require a large construction crew for a brief amount of time. Afterwards similarly to previous pipelines, the need for permanent full-time employees will be few.

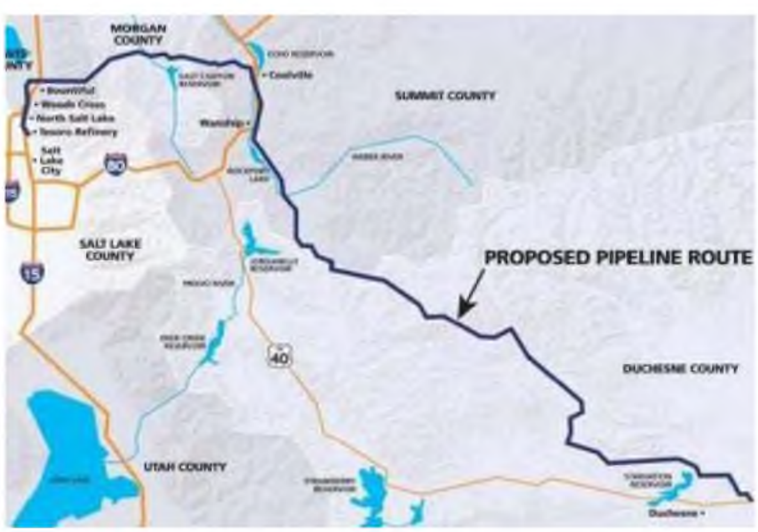


Figure 2.8: Proposed Pipeline Route: One of the Proposed Routes [17].

2.5.2 Types of Jobs

The UNEV Pipeline is an ideal example when comparing the proposed Uinta Express Pipeline. Both are similar in length, diameter and operational capabilities. Both are also common carrier pipelines. A common carrier pipeline is a pipeline that is owned, operated, or managed within the state or states for the transportation of crude petroleum, gas, coal, or carbon dioxide to or for the public for hire, or engaged in the business of transporting crude petroleum, gas, coal, or carbon dioxide by pipelines [4]. A similar workforce would need to be employed to complete the project. During the UNEV pipeline construction, many people with varying skills were employed to carry out the project such as welders, Foreman, and dozer operators. Table 2.4 details the personnel that are needed for the project. From the beginning of grading the surface and excavation to refilling the landscape once the pipe has been installed. At the end of the project the 18 permanent positions will oversee the daily operations of the pipeline. 16 of those positions will be spread out in the major cities the pipeline goes through: Salt Lake City, Cedar City and Las Vegas Nevada. The operations personnel will be equipped with the tools and equipment required to inspect the pipeline to insure functionality. The operations personnel will monitor and control the system 24 hours a day 7 days a week.

Table 2.4: Construction Equipment and Personnel Required for Pipeline: Some of the personnel required to construct the pipeline [4].

EQUIPMENT	PERSONNEL
Grading	
1 Pickup	1 Foreman
1 Dozer	2 Dozer Operators
Excavation (Normal Terrain)	
1 Pickup	1 Foreman
1 Trencher	1 Operator
1 Backhoe	1 Backhoe Operator
1 Dozer w/ Ripper	1 Dozer Operator
1 Trencher	1 Operator
	4 Laborers
Pipe Crew	
1 Welding Rig	1 Foreman
6 Welding Rigs	6 Welders
1 Crew Cab	6 Welders Helpers
3 Sidebooms	4 Assistants
1 Tow Tractor	3 Sideboom Operators
3 Pick-ups	3 Wrappers
2 Flatbed Trucks	1 Truck Driver
Tie-In/Bending Crew	
2 Welding Rig	2 Foreman
2 Welding Rigs	2 Welders
3 Sidebooms	3 Operators
1 Bending Mach.	1 Operator
2 Pickups	1 Bending Engineer
2 Crew Cab	4 Assistants
1 Backhoe	1 Operator
Lowering	
1 Pickup	1 Foreman
3 Sidebooms	3 Sideboom Operators
3 Cradles	2 Welders
2 Welding Rigs	2 Assistants
1 Water Pump	1 Oiler
1 Holiday Detector	5 Laborers
Backfilling	
1 Pickup	1 Foreman
1 Crew Cab	1 Backfill Operator
1 Dozer	1 Dozer Operator
1 Backhoe	1 Backhoe Operator
1 Backfiller/Front-end Loader	1 Oiler, 2 Laborers

2.5.3 Job Losses

In the last decade the production of crude oil in Duchesne and Uintah counties has improved drastically. In 2004 the production of crude oil was about 30 thousand barrels of oil per day, since then the production has increased steadily at about 11.2% every year [17]. Currently, the Uinta Basin produces about 80 thousand barrels of oil per day as show in Figure 2.9. The crude oil that is found in these areas are is of much higher quality and is located in shallower wells making it easy for companies to access. Due to the increased production of oil in the Uinta Basin, and a need for companies to transport the oil to the refineries in Salt Lake City, hundreds of oil tanker-trucks drivers have been employed to move the crude oil to the

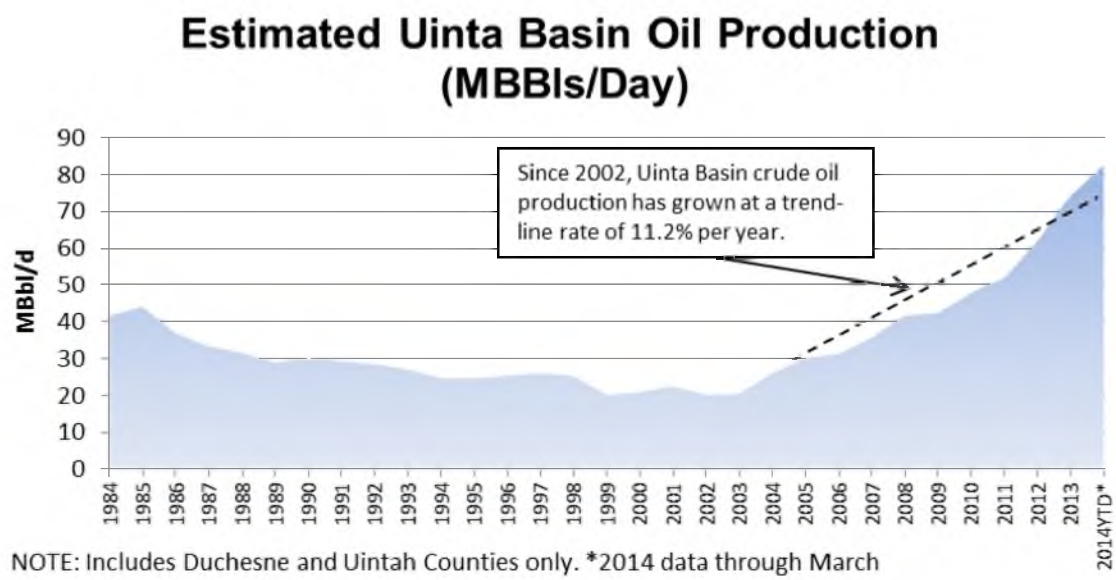


Figure 2.9: Estimated Uinta Basin Oil Production: Shows the increased rate of production in the Uinta Basin [17].

refineries [18]. It is estimated that by the end of 2016 when construction is scheduled to end and operation is scheduled to begin, the pipeline will reduce the number of trucks by 250. Meaning that hundreds of people will be lose their jobs. In the Keystone XL Pipeline and the UNEV Pipeline the amount of permanent jobs that were created were only a few. The new Uinta Express pipeline wont we be an exception. The few permanent jobs that will be created, will not offset the amount of jobs that will be lost.

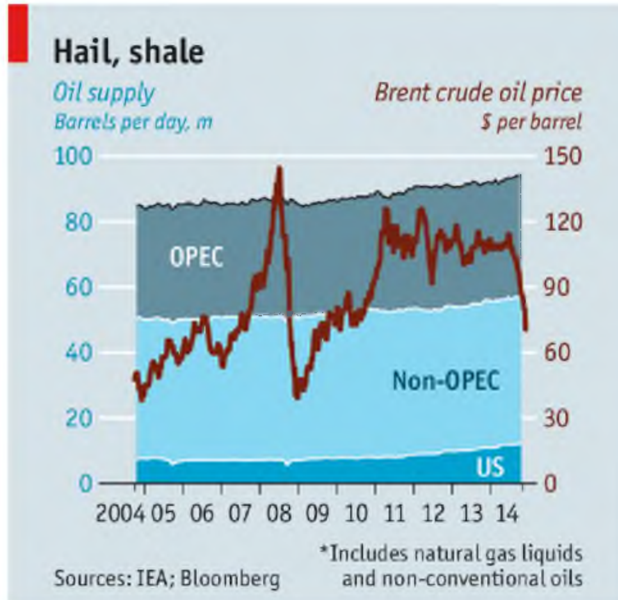


Figure 2.10: Production and Cost of Oil: Comparison of the OPEC, Non-OPEC, and US cost and oil production [22].

2.5.4 Analysis

There are still many factors that need to be assessed before a decision can be made on whether or not building the pipeline is beneficial for the state of Utah. Economically the pipeline will be a tremendous asset and boost to the economy. However, taking only into consideration the current number of total jobs created vs. the total amount of jobs lost the amount of jobs lost far outweighs the jobs created. This makes the pipeline undesirable to the people who will lose their jobs, however not building the pipeline will be a bigger detriment on the economy and has the potential of causing even further job losses in the future. Building the pipeline is not ideal for current tanker truck drivers but if it is not built many more jobs will be lost or not created.

2.6 OPEC's War on US Oil

US oil production has been increasing in the last couple of years like never before seen. These levels could reach to "levels not seen since the 1970s, despite OPEC's efforts to muscle out American shale producers, [...] adding another million barrels a day during 2015 from the current 9 million barrels a day" [19]. After their conference in Vienna on November, 2014, the group of 12 nations with high oil production showed an unwillingness to reduce production. The high production of oil will therefore continue to drop the cost per barrel, which are already lower than $70, down from about $110 in July, as shown in Figure 2.10 [20]. OPEC's decision to keep the same rate production clearly shows an effort to limit new drilling and to hit high-cost wells, particularly those in the US. Since the recent boom in new technologies that make drilling tight oil more efficient and cost effective, the

US has "turned around its fortunes […] in less than a decade, and is expected to drill the most-efficient wells," allowing production to continue to grow even with lower prices [19].

In fact Saudi Arabia, "OPEC's largest producer in oil expects prices to stabilize around $60 a barrel" [21]. These prices remain acceptable to only a few countries producing oil at very low costs. For example, Saudi Arabia "can also weather a low price: its production costs are $5-$6 a barrel—the lowest in the world," compared to other companies in the US that produce barrels at $65 a barrel, and can be compared in Figure2.11 [20].

2.6.1 US Oil Production Is Predicted to Slow

Even with a low price on the barrel, some analysts believe US oil production will not be affected. "The Fed in its last Beige Book made note of the fact that drilling activity in shale production districts remained steady even with a sharp drop in crude prices. [For example,] North Dakota showed an increase in November, and the Fed said officials there expect production to continue increasing over the next two years" [19]. Citigroup analysts also "expect production to rise, and in 2015, it should be in line with the 1 million barrels a day of production growth this year" [19]. But the low prices of oil suggests investment cuts in the shale oil industry will slow American shale production to a crawl and perhaps even lead to slight declines" [22].

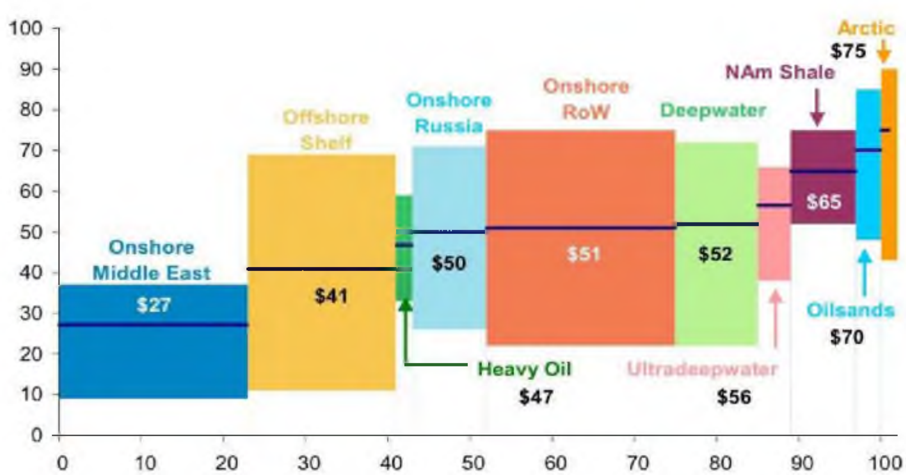


Figure 2.11: Crude Cost of Production Rises as Demand Grows: x-axis: total liquids production; y-axis: average Brent-equivalent breakeven price, $/bbl [21].

2.6.2 Impact on UEP from Low Oil Prices

The international affairs on oil have drastic implications on the UEP, particularly because oil production in the Uinta Basin might no longer be profitable for the time being and prices of oil jeopardize the construction of the pipeline. While many analysts believe the cost of the barrel will decrease to levels as low as $30-$40, they also believe the cost of the barrel must go back up [20]. This brings into question whether it is the right time to invest millions of dollars in oil infrastructure. While the cost of oil is a major issue, there could be benefits to completing the UEP for Utah's future. OPEC's goals may come true over the next short period of time, but many analysts believe the "adversity will eventually make shale stronger. It will prompt a new round of innovation, from cutting drilling costs through standardization to new fracking techniques that increase output" [22]. Even if oil production comes to a complete halt, "when prices recover, new wells can be brought on stream in weeks, not years," restoring production in a very short period of time [22]. The overall prediction is that there will be a shale crash—and a rapid rebound. If and when this happens, Utah will have the infrastructure ready to meet demands and thrust Utah's economy forward.

2.7 Conclusion

In conclusion, this chapter analyzed the economic impact and poly regarding the proposed Uinta Express Pipeline. It is clear to see through the large majority of this report that it is most beneficial economically to construct the Uinta Express Pipeline. In a sole financial perspective, it would be to Utah's best interest to construct the pipeline, generating large sums of revenue trickling down to local economies spread across the state. There are obvious negative impacts of the construction of the Uinta Express Pipeline, specifically environmental issues, which will be discussed in further chapters of this report.

2.8 References

[1] M. Collier, "Uinta Basin: An Unconventional Future," Temper of the Time Foundation, 2014. [Online]. Available: http://utah-oil.com/. [Accessed 10 December 2014].

[2] EIA, "U.S. Energy Information Administration," November 2014. [Online]. Available: http://www.eia.gov/petroleum/marketing/prime/. [Accessed 28 November 2014].

[3] A. Swift, "Will Keystone XL Pipeline Creat Many Construction Jobs?," March 2014. [Online]. Available: http://www.livescience.com/38735-putting-keystone-pipeline-job-numbers-in-context.html. [Accessed 05 December 2014].

[4] b. o. L. Management, "Draft Environmental Impact Statement for the UNEV Pipeline," U.S. Department of the Interior Bureau of Land Management Utah State Office, 2012.

[5] "Impact of Longhorn Pipeline on Economic Activity in Texas and Selected Regions," November 2014. [Online]. Available: http://epa.gov/region6/6en/xp/longhorn_nepa_documents/lppapprsa.pdf. [Accessed 5 December 2014].

[6] G. Walker, "Final Supplemental Environmental Impact Statement for the Keystone XL Project," United States Department of State Bureau of Oceans and International Environmental and Scientific Affairs, Washington, DC, 2014.

[7] N. Snow, "Utah's crude transportation options include Uinta Express project," Oil and Gas Journal, Houston, 2014.

[8] D. House, "Utah refinery growth promises jobs, revenue, but at what cost?," The Salt Lake Tribune, 30 November 2014.

[9] IEA, "Key World Energy Statistics 2014," [Online]. [Accessed 8 November 2014].

[10] "United States Environmental Protection Agency," 25 June 2012. [Online]. Available: http://www.epa.gov/oecaerth/basics/nepa.html#process. [Accessed 5 Dec. 2014].

[11] A. J. O'Donoghue, "Tanker spills, pipelines raise questions about crude oil transport," Desert News, 30 April 2014.

[12] L. Crawford, "Live Summit County," Summit County, 2014. [Online]. Available: http://www.co.summit.ut.us/564/Uinta-Express-Pipeline. [Accessed 5 Dec. 2014].

[13] "Title 78B Chapter 6 Section 501," 2014. [Online]. Available: http://le.utah.gov/~code/TITLE78B/htm/78B06_050100.htm. [Accessed 5 Dec. 2014].

[14] A. Osowski, "The Park Record," 15 April 2014. [Online]. Available: http://www.parkrecord.com/summit_county-news/ci_25572392/francis-residents-concerned-about-uinta-express-pipeline-route. [Accessed 5 December 2014].

[15] T. Corporation, "Keystone XL Pipeline Project," December 2014. [Online].

[16] H. Frontier, "Map of Operations," Holly Energy, June 2012. [Online]. Available: U.S Department of the Interior Bureau of Land Management Utah State Office. [Accessed 05 December 2014].

[17] N. G. Intelligence, "NGI's Shale Daily," Natural Gas Intelligence (NGI), 30 January 2013. [Online]. Available: http://www.naturalgasintel.com/uintainfo. [Accessed 05 December 2014].

[18] N. Snow, "Utahs Crude Trasportation Options Includes Uinta Express Project," Oil and Gas Journal , vol. 112, no. 09, pp. 49-51, 2013.

[19] P. Domm, "OPEC won't stop US oil production growth," CNBC, 3 December 2014.

[20] The Economist, "OPEC: Making the Best of a Low Price," The Economist Newspaper, 6 December 2014.

[21] S. Said, S. Kent and B. Faucon, "Saudi Arabia Sees Oil Prices Stabilizing Around $60 a Barrel," Wall Street Journal, 3 December 2014.

[22] The Economist, "Shale Oil In a Blind," The Economist Newspaper, 6 December 2014.

[23] United States Department of Agriculture, "Forest Service," 2014. [Online]. Available: http://www.fs.usda.gov/uwcnf. [Accessed 10 December 2014].

Chapter 3

Environmental Impacts: Vegetation, Wildlife, and Wetlands

Abstract

The preservation of the natural environment is essential in guaranteeing the safety, health, and welfare of present and future generations. The construction of large scale civil engineering projects, such as pipelines, can have significant negative impacts to the environment. The Environmental Impact Statement (EIS) serves as an important process in requiring engineers to accurately and completely assess the environmental impacts of a project and help preserve the environment.

The Uinta Express Pipeline (UEP) is a large scale civil engineering project that could affect a significant amount of previously preserved environment and requires an EIS. A majority of the EIS will encompass the impacts and related mitigation strategies of the vegetation, wildlife, and wetlands affected by the UEP. This chapter analyzes the possible significant impacts to 1) vegetation from the UEP include disturbance of vegetation, effects to threatened and endangered species, and the spread of noxious weeds. Impacts can be mitigated through the minimization of vegetation removal and proper revegetation strategies. 2) Wildlife from the UEP include habitat destruction, migration disruption, and effects to threatened and endangered species. Impacts can be mitigated through minimization of habitat removal, habitat rehabilitation, construction timing, field studies, and pipeline relocation. And 3) wetlands from the UEP include filling, draining, polluting and introduction of invasive species. Impacts can be mitigated through proper wetland assessment methods, environmentally sound construction techniques, and prevention of possible pollutants.

The findings of preliminary research show that the UEP may not have a significant impact to vegetation, wildlife, and wetlands. Extra care shall be taken to prevent oil spills and further assess impacts to threatened and endangered species. In the end, supplemental field research on the affected environment and completion of the EIS is recommended to completely analyze the environmental impacts.

3.1 Introduction

Since the industrial revolution, the impacts of human activity on the environment had been more or less unknown and disregarded. But as the impacts became larger and the knowledge of the natural world increased, humans began to realize the effects of their activities on the environment. This increase in awareness and proliferation of knowledge led to a recognition of the importance of preserving the environment. Environmental concern has spread into education and has begun to become a socially accepted issue for much of the public and is one of the major controversial issues surrounding the Uinta Express Pipeline (UEP).

The UEP project has the potential to encompass several different types of environmental impacts, and the impacts may vary in degree of their effect to the environment. This chapter is concentrated on the UEP's impacts to vegetation, wildlife, and wetland/riparian areas in the context of an Environmental Impact Statement.

3.2 Environmental Impact Statement (EIS)

The Environmental Impact Statement (EIS) is an important part of many civil engineering projects. The EIS provides important insight to the environmental impacts surrounding a project and can lead to key alterations aimed at minimizing the impacts of the project.

3.2.1 EIS Background and Purpose

The National Environmental Policy Act (section 102(2)(C)) states that any projects and programs that are "entirely or partly financed, assisted, conducted, regulated, or approved by federal agencies," and may have significant impacts on the human environment require the preparation of an EIS [1]. The purpose of the EIS is to provide a thorough analysis of the environmental impacts of a proposed project and promote cooperation and communication between the stakeholders of the project [1]. The stakeholders may include the organizations behind the project, state and federal agencies, landowners, private organizations, and the affected public. The UEP has been evaluated as having potentially significant impacts and will require the preparation of an EIS [2].

3.2.2 EIS Content

The majority of the EIS requires the research of the possible alternatives, the environment affected by these alternatives, and the impacts each alternative has [1]. The UEP project has previously identified possible alternatives for the pipeline from which the affected environment can be identified. The project has also completed preliminary research on the potential impacts of the pipeline [2]. For the purposes of this report, the EIS requirements are condensed to provide a generalized assessment of the affected environment[1] and to focus on the impacts of the UEP on vegetation, wildlife and wetland/riparian areas.

3.2.3 EIS Impact Components

The report attempts to address the key components necessary for the impacts section of the EIS. The impacts researched in the report are meant to emphasize real environmental issues and include direct, indirect, and cumulative impacts [1]. Proposed alternatives and mitigation measures intended to minimize the impacts are also included in this report [1].

3.3 Impacts to Vegetation

The potential impacts of the UEP to vegetation can be divided into four main categories: the disturbance of vegetation, revegetation processes, impacts to threatened and endangered plant species, and impacts from noxious weeds. The categories are representative of typical impacts addressed in the EIS and demonstrate preliminary research needed in the creation of the UEP's EIS [1].

3.3.1 Disturbance of Vegetation

Due to the underground nature of this pipeline, vast quantities of soil will need to be disturbed to construct the pipeline which means vegetation within the Right-of-Way (ROW) of the pipeline will be removed [3]. Although necessary to construct the pipeline, the clearing of vegetation presents two major problems: the destruction of

---

1 The affected environment will include the general region in which all of the pipeline routes are located. The "no-build" alternative of the project is not taken into consideration in this report.

the ecosystem and potential for erosion. To limit the impact of these problems, vegetation removal should be limited to the minimal area practicable within the ROW [4].

3.3.1a Ecosystem Destruction

Vegetation plays a fundamental role in all ecosystems as the foundation of life in the ecosystem as it is at the bottom of the food chain from which all other life depends on. Vegetation also plays important roles in cleaning the water and air in an ecosystem as well as providing wildlife habitat. The larger vegetation including woody species such as trees are especially crucial in these ecosystems as they provide shelter for many different wildlife species especially birds.

The disturbance of soil leaves the ecosystem in an altered state which can have both positive and negative consequences. Different types of vegetation will often grow in the disturbed areas than what was originally present [5]. There are many plant species which will repopulate disturbed areas. Many of these species are noxious weeds[2] which can overrun and destroy ecosystems. The growth of new and different vegetation can also cause a decrease in habitat for wildlife. Ground disturbances, however can also lead to increased plant species diversity in the ecosystem which can be beneficial to ecosystems [5].

Because the UEP is an underground pipeline, the removal of vegetation cannot be avoided. The next best option to minimize the impact to the ecosystem is too minimize the area to be cleared and the amount of larger vegetation to be removed. The overall impact of the UEP on ecosystems should remain relatively small, though, as most the clearing to be done will be one long narrow strip instead of more consolidated clearing operations.

[2] Noxious Weeds are discussed in more detail in Section 2.5 of this report.

This will lead to the impact of more ecosystems, but the ecosystems that are impacted will effected less than centralized clearing operations [3]. The clearing of vegetation for a large building or agricultural purposes could devastate an entire ecosystem and leave none of it left to survive [5]. In this sense, the clearing of vegetation for the pipeline will most likely have a lower net impact on ecosystems in general[3].

3.3.1b Erosion Control

Vegetation also plays a crucial role in controlling erosion. Vegetation helps to hold the soil down and prevent erosion [4]. Without vegetation, the soil will be at the mercy of erosive forces. Figure 3.1 illustrates the increase in erosion that occurs due to the removal of vegetation as well as other highlights major factors that contribute to erosion.

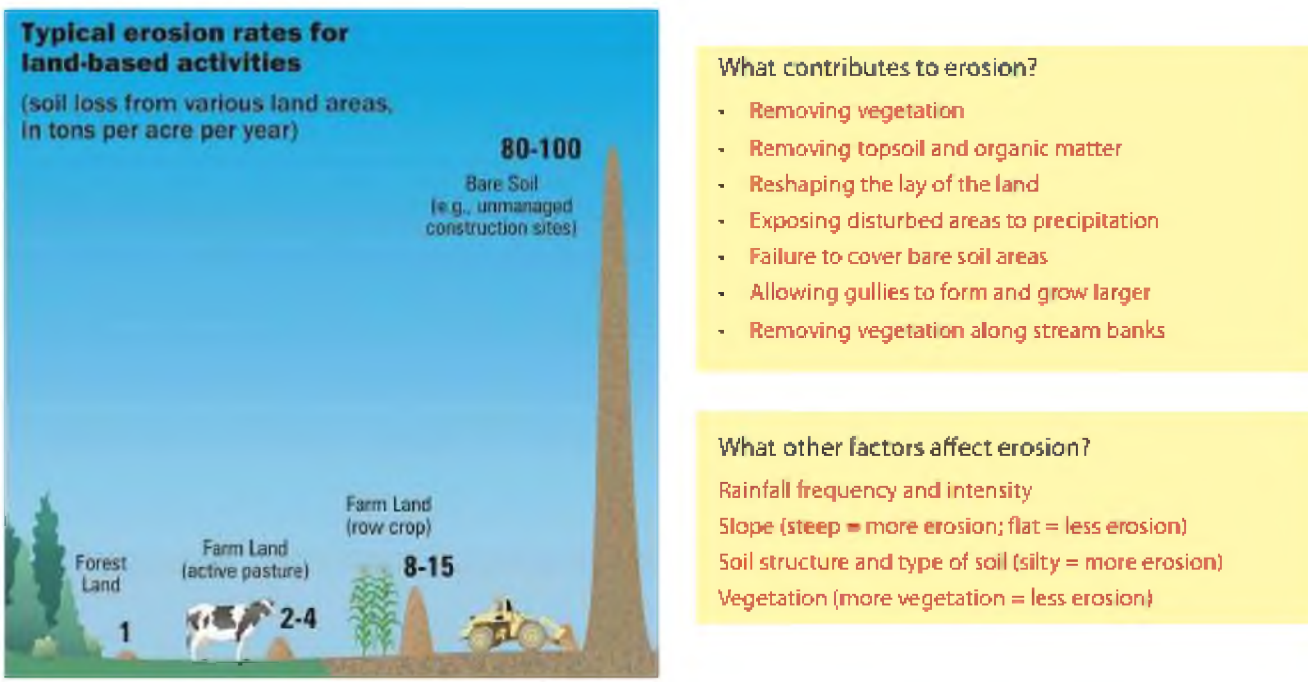


Figure 3.1: Typical Erosion Rates and Factors [4].

---

[3] These size and location of accompanying facilities remains unknown at this time, so emphasis will be on the impact of the pipeline upon vegetation.

Erosion control will represent one of the biggest problems with vegetation removal on this project, since the impact to ecosystems will be fairly small. This pipeline traverses a variety of terrain and the steeper and more exposed areas will be especially problematic. Revegetation efforts must be employed as soon as practicable to help mitigate erosion along the pipeline ROW. Erosion control structures may be implemented, but the cheapest, most environmentally sound, and long lasting erosion control is vegetation [4].

3.3.2 Revegetation

To offset the pipe line's major impacts to vegetation the disturbed areas will need to be revegetated. The revegetation of disturbed areas promotes "greater recovery of natural ecosystem structure and function, and helps safeguard complex plant–pollinator and plant–animal interactions vital to ecological health" [6]. Revegetation helps to mitigate the spread of noxious and invasive weeds, stops erosion, and is useful for determining whether the "corridor will be a healthy environment providing vital ecological services—or a damaged environment presenting more problems" [6]. Revegetation[4] on this project can be broken into three major steps: furnishing and distribution of topsoil, seeding or planting, and monitoring [7] [8].

3.3.2a Topsoil

Topsoil is an extremely important factor in the success of revegetation activities. Without topsoil, new vegetation is not able to grow. Topsoil need be stockpiled during construction and redistributed over the disturbed area after construction is complete [7]. If topsoil does not come directly from the project site, the source should be sampled and the topsoil evaluated for acceptability [7]. Acceptable topsoil will need to be upheld to UDOT standards shown below in Table 3.1.

[4] Because pipeline projects share much in common with highway transportation projects, the proposed revegetation standards will be derived from the Montana Department of Transportation and Utah Department of Transportation standard specifications and manuals. The UDOT standards have been chosen because this project occurs in Utah, and the MDT standards have been chosen based on their stringency towards environmental protection compared to other transportation agencies.

Table 3.1: UDOT Topsoil Standards [8].

Topsoil must be free of:	
Subsoils unfit for vegetative growth	Rock larger than 3" in dimension
Coarse sand and gravel	Trash, litter, or refuse
Stiff clay, hard clods, or hard pan soils	Noxious weeds and weed seeds

Topsoil shall be spread over all disturbed areas to a depth of at least 4 inches to allow the growth of new vegetation. Slopes that are covered with topsoil need be scarified and/ or protected with proper erosion controls and seeding should occur within 48 hours of finished disturbance to prevent the loss of topsoil [7] [8]. Topsoil must be monitored to ensure erosion does not occur.

3.3.2b Seeding

Once the topsoil has been placed, it will need to be prepared for planting. Depending on the method of planting to be utilized, seed bed preparation will vary. For most seeding, the topsoil will need to be scarified to allow seeds penetration [7]. Seeding should commence within 48 hours of bed conditioning and will include one or all of the following methods: broadcast, drill, or hydraulic seeding [7].

Broadcast seeding: Involves manual labor and mechanical broadcasters to physically spread seed across the conditioned seed bed as shown in Figure 3.2.

Figure 3.2: Broadcast Seeding [4].

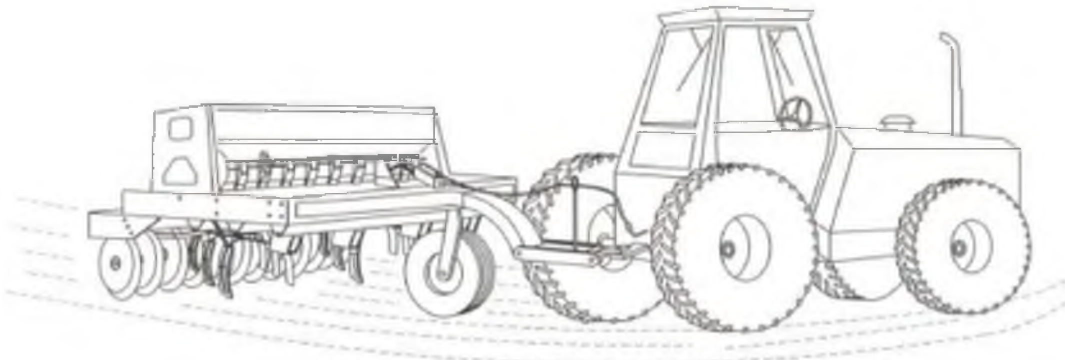


Figure 3.3: Drill Seeding Equipment [4] [9].

Drill Seeding: Involves mechanical equipment that buries seeds as it spreads across the conditioned seed bed as seen in Figure 3.3.

Figure 3.4: Hydraulic Seeding [4].

Hydraulic Seeding: Involves mechanical equipment to spray a combination of seed fertilizer and mulch across the conditioned seed bed as shown in Figure 3.4.

Depending on the conditions on the project site, mulch and fertilizer may also be utilized to ensure the growth of vegetation. Seed mixtures should be certified weed free and contain only native and local species and that represent the native vegetation population that existed prior to construction. Seeding should occur within the proper growing seasons. Growing seasons will vary based on climate, elevation, and species to be planted [7] [8].

3.3.2c Other Planting Methods

Other planting methods include planting live cuttings or sodding [8]. Live cuttings are very effective in riparian and wetland areas where larger woody types of vegetation are desired. Live cuttings often result in faster and more permanent growth [7]. Sodding is the placement of strips of grass-like vegetation which has been removed to the roots and maintains up to several inches of topsoil. Sod should contain only native species and should be placed with a fertilizer application [7]. Sodding offers a more stable alternative to highly exposed areas where seed may be unable to remain in the topsoil or grow effectively.

3.3.2d Monitoring

The revegetation efforts will need to be monitored to ensure that adequate growth occurs. If areas do not see growth, different methods of revegetation should be applied [7] [8]. Monitoring will help to catch any areas where seed may have been lost or revegetation did not take for whatever reason. Monitoring will also ensure the prevention and discontinuation of any erosion that is occurring on the project.

3.3.3 Threatened and Endangered Plant Species

The UEP project carries the potential to impact many threatened and endangered (T & E) plant species. Endangered species are defined as species with a probability of worldwide extinction; whereas, threatened species are defined as species threatened with becoming endangered [10]. The impact to the T & E species listed in Table 3.2 will need to be minimized and mitigated according to the requirements that the U.S. Fish and Wildlife will impose after the completion of the EIS. This section will include preliminary research into the potentially affected T & E species as well as possible strategies to minimize and mitigate impacts.

3.3.3a Potentially Impacted T & E Plant Species

The UEP has the potential to affect the following T&E plant species shown in Table 3.2. A complete list of potentially impacted T&E species listed by county is available in Appendix I.

Table 3.2: T&E Plant Species Potentially Impacted by UEP [10].

Species	Status
Ute Ladies'-tresses	Threatened
Shrubby Reed-mustard	Endangered
Pariette Cactus	Threatened
Uinta Basin Hookless Cactus	Threatened
Barneby Ridge-cress	Endangered

The potentially impacted species were determined by analyzing the counties through which the UEP would cross then researching the T&E species present in each county. The alternative route maps are shown in Appendix I.

3.3.3b Strategies to Minimize Impacts

Many different strategies to help minimize the impact to threatened and endangered plant species have been cultivated through various past transportation projects. These strategies can be broken into two categories: prevention and mitigation. Prevention strategies avoid the impact to a plant species all together, whereas mitigation strategies work to reverse some of the impact to the species. For this section a case study from a pipeline project in California is utilized to assess and determine potential strategies to minimize pipeline impacts.

3.3.3b.i Case Study Background

In California, during the 1980s, several pipelines were created to carry oil from the West coast to refineries in the inland U.S. The pipelines and associated facilities impacted approximately 35 threatened and endangered plant species [3]. Throughout the construction of this project several strategies were employed and assessed based on their ability to minimize the impact to the rare plant species. As shown in Table 3.2, the UEP has the potential to affect only five known T & E plant species which is a much less significant impact than the California case study.

3.3.3b.ii Strategies

To minimize the impact even further, several strategies utilized in California are presented as options for the UEP.

Relocation of Facilities and Pipelines: This strategy involves the relocation of pipelines and facilities in attempt to completely avoid impacts to T & E species. In the California case study, this strategy was utilized to completely prevent the removal of several different plant species [3]. This strategy provides the least impact and risk to T & E species, but is also the most costly and time-consuming alternative.

On-site Mitigation: On-site mitigation includes offsetting the removal of plant species by reestablishing the impacted plant species at the project site. If the pipeline or facilities mandated the removal of a T & E species, the species would be replanted (via methods of seed collection, cuttings, or transplanting) at the same site once construction was complete. For the California pipelines, the replanting of T & E species proved very effective. Several different species were replanted through several different methods and each species successful returned to the revegetated construction sites [3]. This strategy is offers a greater impact and risk to T & E species as the replanting of the vegetation is not a guaranteed success. This strategy is less expensive than relocation, but an increased cost is expected as revegetation efforts will require special implementations to ensure regrowth of T & E species.

Off-site Mitigation: Off-site mitigation includes offsetting the removal of plant species by reestablishing the impacted plant species at a location other than the project site. This strategy employs the same methods as on-site mitigation except replanting occurs at locations off of the project site. In the case study, off-site mitigation proved very successful and resulted in the establishment of some very large rare plant preserves [3]. This strategy presents the largest impact to T & E species as it results in their relocation from their original habitat. This strategy also carries the same amount of risk as on-site mitigation as the replanting of vegetation is never guaranteed to be successful. Off-site mitigation is as expensive if not more expensive as on-site mitigation as additional land must be acquired in supplement to potentially expensive replanting methods.

3.3.4 Noxious Weeds

The spread of noxious weeds is "one of the major global environmental tribulations of today" [11]. The construction of the Uinta Express Pipeline will require the disturbance of vast quantities of soil. Every time soil is disturbed there is an increase in the "susceptibility to invasive plant establishment." If noxious weeds are not controlled they may out-compete the native vegetation and can compromise entire ecosystems [11]. Weed control and prevention is a very large issue in the construction of the Uinta Express Pipeline. This section serves to identify noxious weed species of concern for Utah and propose strategies for controlling and preventing the spread of noxious weeds.

3.3.4a Noxious Weeds in Utah

Nineteen plant species are considered as noxious weeds in Utah. The species are listed below in table 3.2.

Table 3.3: Plants Recognized in Utah as Noxious Weeds [12].

Noxious Weed Common Name	
Russian Knapweed	Quack Grass
Hoary Cress	Leafy Spurge
Musk Thistle	Dyers Woad
Diffuse Knapweed	Perennial Pepperweed
Yellow Starthistle	Purple Loosestrife
Spotted Knapweed	Scotch Thistle
Squarrose Knapweed	Perennial Sorghum
Canadian Thistle	Johnsongrass
Field Bindweed	Medusahead
Bermudagrass	

3.3.4b Proposed Weed Control Methods [7]

- Clean and inspect all equipment prior to transport into the project area to ensure no noxious weeds or invasive species are present.
- Monitor all construction areas to prevent the infestation and growth of noxious weeds and invasive species.
- Herbicide Application: must be conducted in compliance with local, state and federal regulations. Should not be applied to areas that have received final plantings in the revegetation process.
- Mechanical or Hand Pulling Methods.

3.4 Impacts to Wildlife

Many Species of animals live in the area where the Uinta Pipeline will be built. Some will be pushed out of their homes during the construction, and some will be negatively affected finding food or a mate. Because of this, the EIS will require an in depth look into the impacts to animals by the UEP [1]. This section serves as preliminary research to the impacts to wildlife, especially with regard to T&E wild life species.

3.4.1 Animal Species Potentially Impacted

There are numerous species of reptiles and birds that live in the Uintah Basin. The reptiles live mostly in desert environments and rely on the small mammals for their food supply [13]. The bird species live throughout the affected counties and may be slightly impacted by tree removal on the project [7]. To consolidate research and follow the EIS format more closely, research will be mostly focused on the mammals affected by the UEP. Appendix II shows mammals in Utah that may be impacted.

3.4.2 Habitat Destruction

The most significant impact to wildlife by the UEP is habitat destruction. Habitat destruction is the primary threat to wildlife in the U.S. When an ecosystem is changed it may not be able to provide the necessary food, water or shelter. Animals are losing suitable habitats to raise young everyday [14]. The pipeline would not destroy all of any one single habitat, but it would suffer from habitat fragmentation and degradation, which can affect species looking for food or a mate.

The UEP will travel through numerous Aspen and Spruce groves. These trees provide valuable habitat for Utah's native bird species [14]. Along with native birds, many migratory birds stop at the Great Salt Lake for food and rest. These forests proved shelter and for nesting birds as well as migratory birds [7].

It is important to preserve as much land as possible and run the pipeline parallel to existing pipelines. After construction, an effort to rebuild the native vegetation is vital in providing suitable habitat for animals to return. The animals that are pushed out during the construction will hopefully return after the land is rejuvenated.

3.4.3 Migration Paths and Animal Trails

Another potential impact of the UEP is to animal travel. Animals living or traveling underground may have to move homes or change trails with the addition of the pipeline. All animals have to travel whether migrating, looking for food or to find a mate. The Uinta Pipeline could disturb animal trails and migration paths.

A specific example is the migration paths of the mule deer. As shown in Figure 3.5, mule deer migrate through the Uinta basin could be affected during construction. Animals that travel above ground may be disturbed during construction, but the finished pipeline will sit three feet underground so animals should be able to return to their original trails when the pipeline is completed [15]. The best method to encourage animals to return is to reintroduce the native vegetation, and then the animal species will come back. Leaving the area disturbed forces the animals to find homes elsewhere [5].

Figure 3.5: Mule Deer: Hunting locations follow migration trail [15].

3.4.4 The Black-Footed Ferret and Utah Prairie Dog: A T&E Case Study

The UEP has the potential to also affect several different T&E species in Utah[5]. To evaluate the impacts of the UEP on T&E wildlife species, a case study involving the Utah prairie dog and the black-footed ferret is examined further.

[5] Other potentially impacted T&E species listed in Appendix II

3.4.4a Background

When the western prairies were first settled, prairie dogs competed with livestock for food, and ranchers did their best to eradicate prairie dogs [16]. When all the prairie dogs were eliminated the black-footed ferret was left with no food source. Black-footed ferrets were once considered the most endangered mammal in the United States [17]. The ferret was listed as endangered in 1967 and thought to be extinct by 1972. Then in 1981, when a rancher's dog killed a ferret in Wyoming, the rancher brought it to a taxidermist who determined it to be a black-footed ferret. A small isolated population was found in Wyoming and protected and by 1984, 130 wild ferrets were counted. In 1985, the U.S. Fish and Wildlife service captured six Black-footed Ferrets for breeding and today they have more than 500 captive ferrets, and are releasing them into grasslands where they originated [18]. The Black-Footed Ferret is still on the endangered species list and is continually being reintroduced in areas with prairie dog populations. The Utah prairie dog is currently listed as a threatened species [16].

3.4.4b Current Policy

Recently a court ruling ruled that Utah prairie dogs are under control of the state even if they are on private land [16]. This is exciting for the Utah prairie dog and the Black-footed ferret because landowners deem the Utah Prairie dog a pest and want to eradicate them from their property. The Utah prairie dog is considered a threatened species and remains a vital link on the food chain for the endangered Black-footed ferret. Greg Sheehan, director for the Utah Division of Wildlife Resources (DWR) said "We think we can strike a balance that will allow prairie dogs to thrive will allowing landowners better use of their land," [16]. Community leaders, Biologists and DWR officials will have to have a meeting and discuss possible solutions to better manage prairie dogs. The rights of property owners must be respected, while achieving the three goals Sheehan plan must accomplish:

1. Ensure the viability and continued persistence of Utah prairie dogs into the future.

2. Safeguard the health, safety, welfare and property of communities in areas where Utah prairie dogs live.

3. Complement the conservation work the U.S. Forest Service, the Bureau of Land Management and the U.S. Fish and Wildlife Service are doing on federal lands [16].

The Utah Prairie dog must be conserved to protect the endangered Black-footed ferret. Conservation efforts for the prairie dog habitat are increasing their numbers and Sheehan hopes they can soon be taken off the threatened species list [16]. Increasing the numbers of Utah prairie dogs would be the first step in protecting the Black-footed ferret.

3.4.4c UEP Impacts

The Black-footed Ferret is an animal that must be protected when considering the construction of the Uinta pipeline. The Ferret's survival is directly related to the prairie dog populations and since the ferrets have been re-introduced in the Uintah County, they have been growing in numbers [18]. Although the Ferrets are healthy and thriving, it is because of the conservation effort. Figure 3.6 shows land has been designated for ferrets and prairie dogs to live without threat of development.

Figure 3.6: Black-Footed Ferret Range [18].

Construction for the Uinta Pipeline will interfere with Black-footed ferret habitat, but the most important habitats to preserve are prairie dog homes. Ferrets are very adaptable and live in abandoned prairie dog homes. Prairie dogs, however, do not like to change homes or "towns", each one takes a lot of work and labor to build the safe tunnels [16]. Prairie dogs use underground tunnels for shelter and rely on them for survival. Interrupting prairie dog town with a pipeline would possibly eliminate the whole population. They are already at threatened status and the Black-footed ferrets in the area would be left with no food source again. Figure 3.7 shows the Utah prairie dog population from 1970 to 2012 with respect to enlistment on the T&E list.

3.4.5 Potential for Disaster: Amphibians and Oil

The pipeline route will travel next to the Weber River and cross numerous streams [19]. Water pollution could be disastrous if it infects the water table. Amphibians

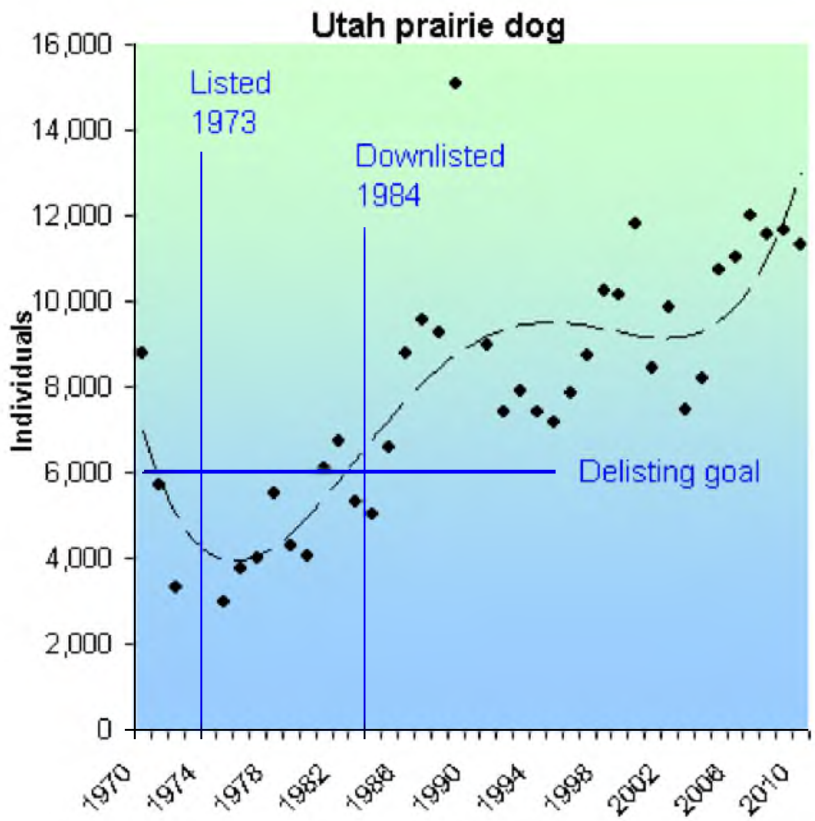


Figure 3.7: Utah Prairie Dog populations [16].

are the most susceptible class of animals to be hurt by pollution or any change in their environment. Amphibian numbers are dwindling worldwide, and can be wiped out of areas from small amounts of pollution [20]. The crude waxy oil that is being transported by this pipeline would have devastating results if disaster occurred and the pipeline spilled or burst [21].The location of the pipeline puts it in extreme risk of polluting entire sections of the Weber River creating a dead zone where no life can be supported [20].

All animals would suffer if there were an oil spill from the pipe, but Amphibians would be the most affected, which makes them the best indicator species to watch for. If the amphibian species are healthy in the Weber River near the Pipeline, it is safe to assume that other animal species are not at risk.

3.5 Impacts to Wetlands

Wetlands are recognized as extremely important ecosystems and are protected by many laws and regulations in the United States. Although it can be argued the UEP may not cross many wetlands, analyzing the impacts to wetlands is another significant step in completing the EIS of any proposed project. The following section briefly overviews wetlands and provides research on the potential wetland impacts of the UEP.

3.5.1 Wetlands Overview

Wetlands play a crucial role in any ecosystem by providing habitat, clean air, and clean water. Wetlands contain habitat for hundreds of plant and animal species and often serve as the most fertile and diverse areas of any ecosystem [22]. Wetlands also act as an enormous filter through which the air and water are cleaned. The numerous species of plants, animals, and micro-organisms quickly break down pollutants in air and water and provide a cleaner environment [22]. Because of their ecological importance, wetlands are highly protected by state and federal agencies, such as the U.S. Army Corps of Engineers. Any action affecting wetlands must be properly permitted, receive approval, and may require additional mitigation [22].

3.5.2 Assessment of Wetlands

The US Army Corps of Engineers define a wetland as “those areas that are inundate or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas” [22]. As shown by this definition, assessing and categorizing wetlands can be very difficult. Throughout the U.S., methods wetland assessment has become largely debated. Many organizations disagree on exactly what constitutes a wetland and often face conflicts during projects due to incorrect wetland assessment [23]. To completely determine the UEP’s impacts on wetlands, assessment methods and classification systems that follow the most stringent and highest ranking agencies’ standards.

Classification systems will help reduce the variability in which wetland conditions are assessed. The main hydrologic conditions that are assessed are the sources of water, vegetation, topography, soil, and landscape characteristics [23]. Many wetlands cannot be judged only on its condition, but on the educational value associated with the land [23]. Establishing a method to measure conditions of wetlands will help establish a fundamental ground that everyone can return to. It is very important to avoid the creation of multiple versions of wetlands assessment. Hydrology, soils, and biota are the basics in characterizing and assessing wetlands. The vegetation will be the main indicator for evaluating wetlands [24].

3.5.3 Leading Factors of Wetland Destruction

220 million acres of wetlands once existed in the continental United States, today less than half of that exists. Roughly 60,000 acres of wetlands are destroyed each year. The leading factors that contribute to wetland destruction are hydrologic alterations, urbanization, industry, and agriculture [24]. Drainage, clearing, and road construction are relates construction activities that could destroy wetlands.

3.5.3a Depositing Fill Material

Since the pipeline is underground dirt will have to cut out to make room for the pipeline. The proper disposal of this soil is crucial for the protection of the wetlands. Placing the soil in saturated areas could potentially change the flow of water, which in time could lead to the destruction of the wetland.

3.5.3b Draining Wetlands

Placing the UEP could potentially start a debate on the drainage of a certain wetland. Construction may

Figure 3.8: Filling Wetlands [24].

seem too difficult on saturated lands and crews may opt to drain the areas. Draining is detrimental to wetlands and need be avoided [24].

3.5.3c Diverting Water Flow

Altering the flow of water in a wetland can also have disastrous impacts on the functions of a wetland [24]. Installing a pipeline through a saturated environment could change the natural water flow. The placement of the UEP through wetlands should be carefully assessed and avoided when possible.

3.5.3d Pollution

Construction activities of the UEP have the potential to pollute nearby wetlands. Fuel and chemical spills from equipment may enter wetlands [7]. Fertilizer used to restore vegetation near the dig zone can lead to polluted wetlands. Nitrogen and Phosphorous are two of the leading nutrients that may affect the health of an ecosystem [24]. To mitigate these impacts, emergency spill kits need to be on construction sites at all times [7]. Fertilizer use should be limited or restricted near wetlands.

Figure 3.9: Draining Wetlands [24].

3.5.3e Invasive Species

Invasive species fight for valuable resources that native Utah species require, and wetlands are especially susceptible. When these alien species gather valuable resources for its survival it takes away that resource from a species that routinely gathers it, and threatens to kill off a percentage of the native species [24]. The Utah recognized invasive species are listed in Table 3.4.

Table 3.4: Invasive Species in Utah [12].

Group	Name
Fungus	Chytrid Fungus
Algae	Didymo (Rock Snot)
Plants	Common Reed Curly-lead Pondweed Eurasian Watermilfoil Purple Loosestrife Tamarisk
Mollusks	Asian Clam Quagga Mussel Zebra Mussel False Darmussel New Zealand Mudsnail Red-rimmed Melania
Crustaceans	Northern Crayfish Louisiana Crayfish Water Nymph Rusty Crayfish
Fish	Burbot Gizzard Shad Western Mosquito fish
Amphibians	Green Frog North American Bullfrog Plains Leopard Frog Rio Grande Leopard Frog
Reptile	Red-Eared Slider

Construction activities hold the potential to bring invasive species to wetlands. Equipment and materials can transport invasive species from other locations [7]. The same procedures provided to prevent the spread of noxious weeds are recommended to prevent the introduction of invasive species on this project.

3.5.4 Wetland Mitigation

Typically, the destruction of wetlands within the U.S. requires offsetting the loss of wetlands by creating new wetlands. Wetland mitigation may occur on the construction site at the affected wetland or off-site at other areas [22]. On-site mitigation is typically preferred as it generates the lowest net impact and leaves the original area in a less altered state [7]. The UEP may involve unavoidable impacts to wetlands, and may require wetland mitigation. It is recommended mitigation occur onsite when wetland impacts cannot be avoided.

3.6 Summary and Conclusions

The final evaluation of the Uinta Express Pipeline's impacts on vegetation, wildlife, and wetlands is found to be minimal. Because the UEP is a linear transportation project, the total area impacted and the level of the impact is decreased. More different types of ecosystems may be affected by the UEP, but no one ecosystem should be impacted severely. The impacts that do occur to ecosystems can be easily offset with proper rehabilitation and mitigation measures for vegetation, wildlife, and wetlands.

The most probable significant impacts of the UEP come in the event of an oil spill or by adversely affecting T&E species. An oil spill from the pipeline holds the potential to destroy entire ecosystems and significantly affect many different species of vegetation and wildlife. T&E species are often much more sensitive to habitat alteration and pose a potential to be adversely affected by the pipeline. T&E plant species are especially susceptible as they cannot avoid pipeline impacts as wildlife might.

Ultimately, this chapter is guided by a limited scope research that can only preliminarily asses the environmental impacts of the Uinta Express Pipeline. It is recommended that field studies and more current research on the affected environment are completed to accurately determine the severity of the possible impacts of the UEP. The EIS can provide this higher level of analysis to the UEP and can offer a more thorough and precise analysis of the environmental impacts surrounding the Uinta Express Pipeline.

3.7 References

[1] Director's Order 12: Conservation Planning, Environmental Impact Analysis, and Decision Making, National Park Service, Wash. D.C., 2012.

[2] Uinta Express Pipeline, [Online]. Available: http://uintaexpresspipeline.com/

[3] A. M. Howard, "Strategies for protecting rare plants from oil developments: a Santa Barbara County perspective," Conservation and management of rare and endangered plants, pp. 409-411, Nov, 1987.

[4] Utah Department of Transportation Erosion and Sediment Control Field Guide, Utah Department of Transportation, Salt Lake City, UT, 2010.

[5] M. T. Sebastia and L. Puig, "Complex Vegetation Responses to Soil Disturbances in Mountain Grassland," Plant Ecology, vol. 199, no. 1, pp. 77-88, Nov, 2008.

[6] K. M. Wilkinson et al., "Native Plants on Disturbed Roadsides: Introduction to a New Integrated Approach," Native Plants Journal, vol. 9, no. 3, pp. 267-277, Fall 2008.

[7] Standard Specifications for Road and Bridge Construction, 2014 ed., Montana Department of Transportation, Helena, MT, 2014.

[8] 2012 Standard Specifications for Road and Bridge Construction, Utah Department of Transportation, Salt Lake City, UT, 2012.

[9] Erosion and Sediment Control Best Management Practices: Field Manual, Montana Department of Transportation, Helena, MT, 2004.

[10] County Lists of Utah's Federally Listed Threatened(T), Endangered(E), and Candidate(C) Species, Utah Division of Wildlife Resources, Salt Lake City, UT, 2012.

[11] M. T. Daab and C. G. Flint, "Public Reaction to Invasive Plant Species in a Disturbed Colorado Landscape," Invasive Plant Science and Management, vol. 3, no. 4, pp. 390-401, October – December, 2010.

[12] Utah State-listed Noxious Weeds, Utah Department of Agriculture, Salt Lake City, UT, 2003.

[13] "Utah Division of Wildlife Resources - Mammals." Utah Division of Wildlife Resources-Mammals N.p., n.d. [Online]. 05 Dec. 2014.

[14] "Habitat Loss," National Wildlife Federation, 2014.

[15] "Mule Deer" Western Association of Fish and Wildlife Agencies, WAFWA, pp. 1-15.

[16] "Developing a Utah Prairie Dog Plan" Wildlife News, Utah DWR, pp. 1.

[17] "Utah Division of Wildlife Resources –Black-Footed Ferret." Utah Division of Wildlife Resources-Mammals N.p., n.d. Web. 05 Dec. 2014.

[18] "Reintroduction of Native Species – Black-Footed Ferret" Colorado Plateau, CPLUHNA.NAU.org, Denver, CO. 1998, pp 1.

[19] Derek Siddoway "Uinta Express Pipeline open house leaves unanswered questions," The Park Record, Park City News, Salt Lake City UT. 2014 pp 1-2.

[20] "USGS Study Confirms U.S. Amphibian Populations Declining at Precipitous Rates" U.S. Geological Survey, USGS. Reston VA. 2013

[21] Nick Snow "Utah's Crude Transportation options include Uinta Express Project" Oil and Gas Journal, pp. 1, PennWell, Houston, TX. 2014.

[22] Recognizing Wetlands: an Informational Pamphlet, US Army Corps for Engineers.

[23] Review of Rapid Methods for Assessing Wetland Condition, Environmental Protection Agency, Corvallis, OR, 2004

[24] Major Causes of Wetland Loss and Degradation, North Carolina University, 1976.

Appendix I: UEP Routes and Potentially Impacted Counties and T&E Species.

Figure 3.10: Proposed UEP Routes [2]

Impacted Counties:

- Duchesne County
- Wasatch County
- Summit County
- Morgan County
- Davis County
- Salt Lake County

Appendix II: Utah's Threatened and Endangered Species

Table 3.5: Complete List of T&E Species by County [10].

County	T&E Group	Name	Status
Duchesne	Birds	Yellow-billed Cuckoo (Coccyzus americanus)	Threatened
	Birds	Mexican spotted owl (Strix occidentalis lucida)	Threatened
	Fishes	Humpback chub (Gila cypha)	Endangered
	Fishes	Colorado pikeminnow (=squawfish) (Ptychocheilus lucius)	Endangered
	Fishes	Bonytail chub (Gila elegans)	Endangered
	Fishes	Razorback sucker (Xyrauchen texanus)	Endangered
	Flowering Plants	Shrubby reed-mustard (Schoenocrambe suffrutescens)	Endangered
	Flowering Plants	Barneby ridge-cress (Lepidium barnebyanum)	Endangered
	Flowering Plants	Ute ladies'-tresses (Spiranthes diluvialis)	Threatened
	Flowering Plants	Pariette cactus (Sclerocactus brevispinus)	Threatened
	Flowering Plants	Uinta Basin hookless cactus (Sclerocactus wetlandicus)	Threatened
	Mammals	Canada Lynx (Lynx canadensis)	Threatened
Summit	Birds	Yellow-billed Cuckoo (Coccyzus americanus)	Threatened
	Fishes	Humpback chub (Gila cypha)	Endangered
	Fishes	Colorado pikeminnow (=squawfish) (Ptychocheilus lucius)	Endangered
	Fishes	Bonytail chub (Gila elegans)	Endangered
	Fishes	Razorback sucker (Xyrauchen texanus)	Endangered
	Mammals	Canada Lynx (Lynx canadensis)	Threatened

Wasatch	Birds	Yellow-billed Cuckoo (Coccyzus americanus)	Threatened
	Fishes	Humpback chub (Gila cypha)	Endangered
	Fishes	Colorado pikeminnow (=squawfish) (Ptychocheilus lucius)	Endangered
	Fishes	Bonytail chub (Gila elegans)	Endangered
	Fishes	Razorback sucker (Xyrauchen texanus)	Endangered
	Flowering Plants	Ute ladies'-tresses (Spiranthes diluvialis)	Threatened
	Mammals	Canada Lynx (Lynx canadensis)	Threatened
Morgan	Birds	Yellow-billed Cuckoo (Coccyzus americanus)	Threatened
	Mammals	Canada Lynx (Lynx canadensis)	Threatened
Salt Lake	Birds	Yellow-billed Cuckoo (Coccyzus americanus)	Threatened
	Fishes	June sucker (Chasmistes liorus)	Endangered
	Flowering Plants	Ute ladies'-tresses (Spiranthes diluvialis)	Threatened
	Mammals	Canada Lynx (Lynx canadensis)	Threatened
Davis	Birds	Yellow-billed Cuckoo (Coccyzus americanus)	Threatened

Appendix III: Potentially Impacted Mammal Species

Table 3.6: Hooved Mammals in Utah [13].

Hooved Mammals Common Name	
Moose	California Bighorn Sheep
Elk	Rocky Mountain Bighorn Sheep
Mule Deer	Desert Bighorn Sheep
Pronghorn	Mountain Goat
Bison	

Table 3.7: Predatory Mammals in Utah [13].

Predatory Mammals Common Name	
Badger	Bobcat
Black Bear	Canada Lynx
Grizzly Bear	Grey Fox
Mountain Lion	Red Fox
Fisher	Kit Fox
American Mink	Coyote
Black Footed Ferret	Grey Wolf
River Otter	Long-Tailed Weasel
Ermine	Ringtail

Table 3.8: Small Mammals in Utah [13].

Small Mammals Common Name	
Abert's Squirrel	Masked Shrew
American Marten	Meadow Vole
American Pika	Montane Shrew
Arizona Woodrat	Montane Vole

Beldings Ground Squirrel	Mountain Cottontail
Black Rat	Muskrat
Black-Tailed Jackrabbit	North American Porcupine
Botta's Pocket Gopher	Northern Flying Squirrel
Brush Mouse	Northern Grasshopper Mouse
Bushy-Tailed Woodrat	Northern Pocket Gopher
Canyon Mouse	Northern Raccoon
Cliff Chipmunk	Piute Ground Squirrel
Desert Cottontail	Prairie Dog
Dwarf Shrew	Pygmy Rabbit
Golden-Mantled Ground Squirrel	Red Squirrel
Great-Basin Pocket Mouse	Rock Pocket Mouse
Hopi Chipmunk	Rock Squirrel
House Mouse	Sagebrush Vole
Hopi Chipmunk	Snowshoe Hare
Least Chipmunk	Striped Skunk
Little Brown Pocket Mouse	Uinta Chipmunk
Long-Tailed Pocket Mouse	Western Spotted Skunk
Long Tailed Vole	Yellow-Pine Chipmunk

Chapter 4

Water Quality: Spill Hazards

Abstract
The Uintah Express Pipeline (UEP) will be built next to important sources of drinking and irrigating water. It is important to discuss the impact that the pipeline, and potentially an oil spill, will have on the quality of water. In chapter 4 the Weber River watershed and the bodies of water it contains are described. Also discussed are the ways that land within the watershed is used. Additionally, a detailed report of the water and its current contaminants are contained within the chapter.

The final route for the UEP has not been chosen, therefore a section of chapter 4 is dedicated to discussing the different route options. The route's impacts on the reservoirs, streams, and rivers in the area surrounding the pipeline are determined. Another section focuses on pipe ruptures and how they occur. This is important to describe because during normal operation, the pipeline will not affect water quality. Lastly, the chapter describes pertinent properties of waxy crude as they apply to an oil spill and the potential health affects oil can have on the public in the case of a spill.

4.1 Introduction

This chapter discusses the Weber River Watershed and its present quality as well as how it may affect route selection. Pipelines are prone to leaks and failures that allow oil to enter the environment and watershed. This is important because compounds in the oil are hazardous to human health. The properties of black waxy crude are considered because they affect how oil spills and cleanup develop.

4.2 Current Condition of Weber River watershed

A watershed is defined as "an area that contributes [water] flow to a point on the landscape" [1]. If the "point" chosen is at the mouth of a river, everything that drains into the river is considered that river's watershed. In the case of the Uinta Express Pipeline project, the most important drainage area is the Weber River watershed. Although the Weber River is relatively narrow and shallow along its 125 mile length, its watershed spans over 2,500 square miles across 3 counties and includes 1 other river, 4 major creeks, several reservoirs, and 2,200 miles of perennial and intermittent streams[6] [2].

Within the watershed is the Delta Aquifer (an aquifer being a deposit of underground water). This underground water is used to supplement the water that comes from the Weber River watershed and is also an important resource to monitor and discuss when proposing a buried pipeline's construction. The entire watershed, also known as a basin, is used extensively for grazing livestock or growing alfalfa [3]. This is predominantly because of the mineral rich soil that was deposited centuries ago by ancient Lake Bonneville, making for very fertile soil. As the old lake receded, silts and organic materials were trapped in the mountain valleys of the Weber River Basin [4].

[6] The Ogden River is the other major river that contributes to the Weber. The other creeks mentioned are the East Canyon Creek, Lost Creek, Chalk Creek, and Beaver Creek. Echo, Rockport, Pineview, Causey, East Canyon, Lost Creek, and Smith and Morehouse, and Willard Bay serve as the reservoirs for the basin. All of these bodies of water are located within Weber, Morgan, and Summit counties.

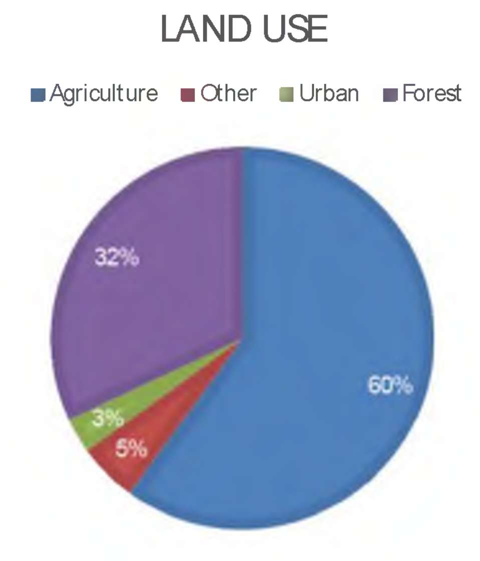


Figure 4.1 Weber River Land Usage [2].

After farming, the second leading land designation of the Weber River watershed is forested area; national forests fill almost a third of the area. The Ashley National Forest, created in 1908, receives over 2.5 million visitors each year and the Uinta-Wasatch-Cache National Forest, which was created around the same time, easily receives over 10 million visits per year due to the ski, and water sports industry [5, 6].

It is important to note that the water that comes from the Weber River basin is stored long term in several massive man-made reservoirs. This allows those downstream to experience a consistent level of incoming water rather than the highs and lows that come from spring run-off and late fall dryness. These storage sites also allow water to be stored through droughts, saved from losses that occur during low river levels, and funneled into hydro-electric dams. While this storage system has many benefits, it also exposes the water to more contaminants [7].

Urban land only accounts for 3% of the total area. The only major urban center in the upper portion of the Weber River watershed is Park City, with a population of only about 8,000 people within city limits. The lower portion of the watershed is much larger in population, and has more sensitive needs than the upper portion. Downstream from the expanse of the Weber River basin live approximately 500,000 people who depend upon the water that comes from the Weber River [8].

Because the main population of Utah is located in a semiarid climate, the state is largely dependent upon its alpine watersheds to provide its water. With the average American using 80–100 gallons of water per day[7], the approximately half-million people serviced by the Weber River watershed demand upwards of 50 million gallons per day. Although some irrigated food is imported from and exported to areas outside of this watershed, the numbers are still staggering. Undoubtedly, the Weber River watershed, including its surface and groundwater, is extremely important to those who consume it [9].

Every year in February, the Weber Basin Water Conservancy District issues a report on the quality of water within the Weber River basin (Appendix I). The report from February 2014 contained information on the water's inorganic, organic, radiologic, and microbiologic contaminants. Most contaminants come from mines, farming, and erosion; however, some contaminants are introduced into the water on purpose because of their overall beneficial effect. An example of this is the addition of chorine into the water which sanitizes it, but also leaves behind trace contaminants [7].

Much of the water in the world contains contaminants that are removed through various methods, so it is no surprise and of no concern to find some contaminants in the Weber River basin. Several reports on water quality conclude that contaminations are appropriate for both irrigation and drinking water coming from the Weber River Watershed[8].

In addition on the WBWCD's report, the water quality department of the State of Utah issues an occasional report on the state's watershed quality. In 2008 the report detailed sources of river and stream water quality impairment (see Figure 4.2). The largest contribution of water contaminants in 2008 came from agricultural sources, followed closely by mining and hydro-modification, or purifying the water [10]. These sources are to be expected as the WBWCD's report frequently mentions fertilizer run-off and material extraction run-off as "typical sources" of contaminants.

---

[2] When considerations are made for showers, flushing the toilet, using dishwashers and washing machines, watering lawns, and eating food from irrigated land, the use of such seemingly-large amounts of water becomes more understandable.

[8] One notable contaminant is Cryptosporidium or Giardia. This is a form of bacteria that is harmful to humans in large amounts. Although they are not able to be removed from water completely, they are able to be kept at bay by shining UV light on the water during purification. This process is done on all water used for drinking that comes from the Weber River (weberbasin.com).

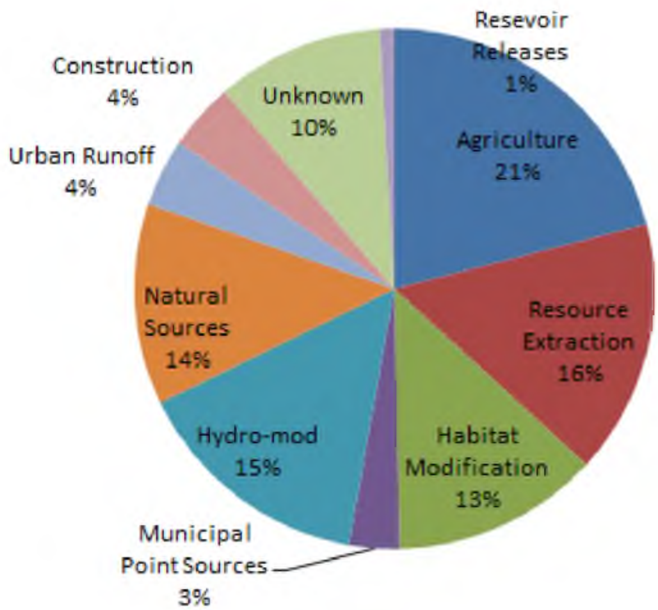


Figure 4.2: Source of Water Impairment [10].

Overall, the water quality of the Weber River watershed is relatively good. With previously reliable methods of monitoring contaminants, and through continued efforts to remove contaminants, it is feasible to imagine a pipeline having a low impact on the watershed it passes through and in turn, the people who drink the water.

4.3 Potential Routes' Impacts on Nearby Water Sources

There are three possible routes identified on which to build the pipeline. The routes are currently being evaluated as part of the project's Environmental Impact Statement, due for release Summer 2015, so the route is far from finalized. Upon release of the EIS, the general public will have a better idea of the effects that a route will have on the Salt Lake Valley's water compared to the others. Indeed, the impact on the Weber River watershed may be one of the most important considerations in determining the optimal route, with the different routes having different relations to the water throughout the area and therefore have different impact.

Of significance are limitations placed on potential construction opportunities by local governments. Specifically, in Summit County, where all three routes have a major presence, there are permitting requirements in place that specifically address the pipeline's physical relationship with water. Under the Eastern Summit County Conditional Use Permit, the pipeline may not be built within 2,500 feet of any water resource. Furthermore, the permit requires "that any stream or river crossing be accomplished by boring 10 feet under the water channel, providing a barrier between the pipeline and the water, and placing isolation valves on either side of the water resource in order to allow immediate shut off in the event of a breach in the pipeline" [11]. Such regulations are an important attempt to balance technical and economic considerations with environmental. All three proposed routes share the same initial 90 miles which parallel the Duchesne River—merely a minor river in the larger context of the relevant watersheds—early on and also come near Starvation and Jordanelle Reservoirs. Upon entering Summit County, the Northern Route diverges north while the other two routes, the East Canyon and Southern routes, stay together. In the Northern Route's lone path, it crosses minor creeks and parallels the Weber River substantially. The route comes quite near Rockport Lake; while it is difficult to make an estimate with the information publicly available, the route approaches the closest allowable proximity to a source of water in Summit County, perhaps within 3000 feet. It then parallels the Weber River again towards Echo Reservoir and winds west through the canyons of the area as it parallels the Kern River Pipeline, discussed further below.

The East Canyon and Southern routes share the same additional 20 miles through the Snyderville Basin after diverging from the Northern Route at Jordanelle. After splitting off from the Southern Route, the East Canyon Route heads north down East Canyon, paralleling East Canyon Creek before coming close to the East Canyon Reservoir. The East Canyon Reservoir is in Morgan County, where restrictions on the pipeline's proximity to bodies of waters are not known. The remaining stretch to Salt Lake City refineries, the East Canyon and Northern routes share the same path with no major waterways in proximity.

The Southern Route heads into Parley's Canyon, crossing directly between Little Dell Reservoir and Mountain Dell Reservoir. Mountain Dell and Little Dell reservoirs are close to one another, and facilities exist to pump water upstream from Mountain Dell to Little Dell, allowing Little Dell Reservoir to receive water diverted upstream from Parley's Creek [12].

Figure 4.3: Ruptured Pipeline: Buried Pipe [13].

Any potential risks, however slim the chances of occurring, must be considered in the context of such proximity to these important bodies of water. In examining these routes, the Northern Route, the preferred route by Tesoro, is seen to have the largest proximity to sources of water, with its sustained paralleling of the Weber River and its approaching several (higher elevation) bodies of water. On the other hand, the existence of the Kern River Pipeline sheds favorable light on the Northern Route. The Kern River Pipeline is an existing pipeline running from Wyoming to California, and makes the proposed construction of the Uinta Express Pipeline along the Northern Route simpler, since the latter would run parallel to the former through an existing cut in the forest. The potential risks to area water must be considered in this context: the effects of pipeline construction through forested areas already exist; therefore, many pitfalls associated with the UEP are lessened.

4.4 Escape Points in a Pipeline

When looking at how the pipeline interacts with the watershed, the possibility of the pipeline releasing the contents out to the environment cannot be overlooked. If a pipeline is releasing its contents from a part of the pipeline that has not been designed to release the content then this can be called an unplanned escape point rupture. Figure 4.3 shows an unplanned escape point that occurred in a buried pipe [13].

Escape points fall into different categories and each need to be assessed individually for the Uinta Express Pipeline to ensure the contents of the pipeline do not escape into the environment. The different ways the contents of the Uinta Express Pipeline can escape into the environment are through: seepage, which is when the material in the pipe goes through the material of the pipe without having a direct path way, leaks that can be caused by large cracks forming from chemical interactions with the pipe material and finally a full pipeline failure which is also called a pipeline rupture. Ruptures can occur in pipelines from different sources of influence including: buckling, shear, chemical corrosion, or tampering. Since the Uinta Express Pipeline is planned to be a buried pipeline, the possibility of tampering is unlikely and will not be discussed in this report.

Seepage is a minor type of escape because the amount of material that escapes the pipeline is small, and seepage can be stopped during the design phases of a project. Since seepage is when the material inside the pipe goes through the material of the pipe, usually by the pours in the material, preventing the seepage is easy and predicable. If the material put through the pipeline is known then the pipe can be designed to fully prevent seepage.

The next two ways material can escape from a pipeline are discussed concurrently. Leakage and rupture are caused by the same influences. The difference is the intensity of the influence. The next couple of sections will talk about the different influences and how they can be prevented or slowed down.

4.4.1 Rupture Risk: Normal fault

Looking at the proposed route of the UEP, it will cross many normal faults. The risk that happens when crossing a normal fault is the chance for the fault to slip and damage the pipeline. The large normal fault that the pipeline crosses is the Wasatch Fault. Figure 4.4 shows a cross section of the Wasatch Fault and movement of shock waves from a theoretical epicenter. The Wasatch Fault is termed a normal fault because the Wasatch Mountains move upward relative to downward-moving estimates layer that is the valley.

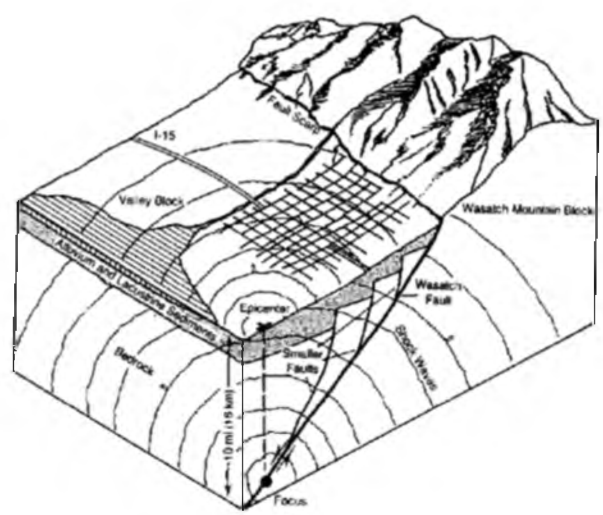


Figure 4.4: Normal fault: Diagram [14].

Since the ground moves when a normal fault slips the pipeline will also move with the ground. Figure 4.5 shows how the pipeline will sit in a rock and soil layer across a normal fault. The picture shows the cross section of a buried pipeline in a soil and a rock layer. As illustrated by Figure 4.5, when the pipeline is placed in rock, soil is still placed as fill. The Wasatch Fault is a unique in that it has a soil layer on the side

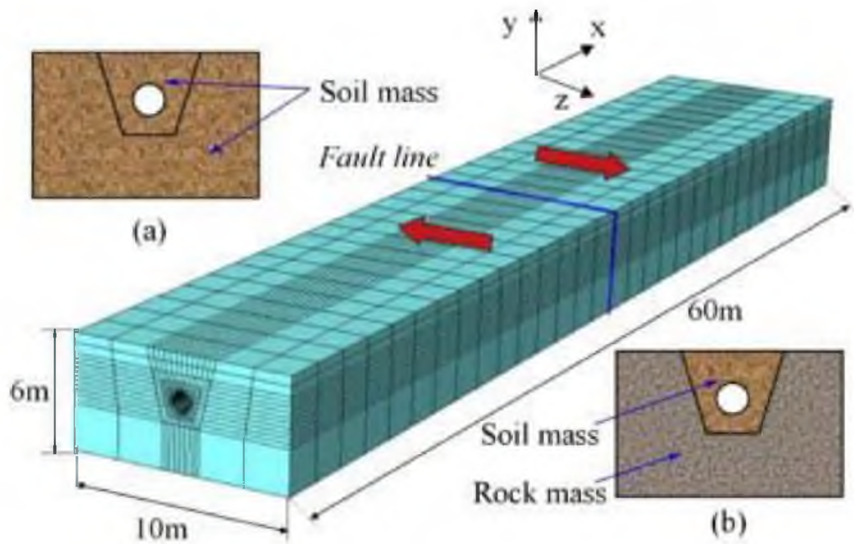


Figure 4.5: Pipeline Placement: Soil vs Rock [15].

of the valley and rock layers on the side of the mountain range. This is potentially problematic because of the difference between how the rock and soil behaves on a normal fault. Figure 4.6 highlights simulations performed by J. Zhang, and Z. Liang in order to illustrate how bucking occurs in a pipeline with different fault line displacements. These simulations indicate that there is a large difference when there is a soil layer compared to the Rock layer. The authors of Buckling behavior analysis of buried gas pipeline under strike-slip fault displacement, analyze the outcomes from there simulations [15].

> There are two buckling locations of the pipeline in soil mass layer. They are in both sides of the fault line, and buckling modes are the same. With the increasing of the fault displacement, buckling is more serious, and local collapse appears. But in rock mass layer, the pipeline was squashed around the fault line. Buckling modes of pipeline in rock mass layer are different with it in soil mass layer. In addition to the backfill soil and layer have a great effect on the buckling modes of buried pipeline under strike-slip fault. The pipeline

> was squeezed more flat with the increasing of the fault displacement. Because of the elasticity modulus of the soil layer is smaller than the rock layer, deformation of soil mass is bigger than rock mass under the action of the buried pipeline crossing the strike-slip fault. [15]

With the Wasatch Fault having a rock layer on one side the conclusion can be made that if the fault were to slip there would be a tremendous collapse in the pipeline over the fault line and the contents of the pipeline would be released. The simulations were only done under conditions where the pipeline had no prior problems. The Uinta Express Pipeline is going to be place in a region that has the possibility of avalanches. There is very low possibility of an avalanche causing the pipeline to rupture because the pipeline is buried, but with the force that an avalanche can cause the pipeline might be dented. If the pipeline has a dent or bend near a fault line the chance for a rupture to occur is greatly increased because the force of the fault has a place to move instead of forcing a place to move.

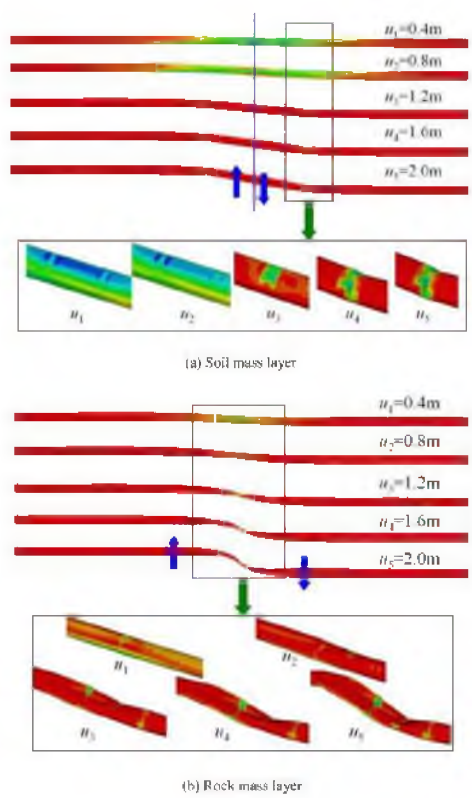


Figure 4.6: Normal fault Simulations: Soil vs Rock [15].

When looking at normal faults there are only a few measure that can be implemented to stop escape points from occurring. One way to stop points from occurring on a normal fault is decreasing the depth the pipeline is buried. At a shallower depth the pipeline can pull out from the ground making the shear force caused by the normal fault have less of an impact on the pipeline. Unfortunately since the Uinta Express pipeline will be heated putting the pipe closer to the surface may affect the surrounding area. However a new process of using Geofoam to protect pipelines is starting to be used. A study conducted by Dr. Barlett at the University of Utah "shows a Geofoam-protected pipeline on the valley side of the Salt Lake City segment of the Wasatch Fault could withstand up to four times more vertical force than traditional soil cover." [16] With the research conducted by Dr. Barlett the Uinta Express Pipeline should be protected from the normal faults it crosses with a Geofoam layer instead of a full soil layer.

4.4.2 Rupture Risk: Chemical Corrosion

Rupture can also occur from corrosion of the pipe material that will cause cracks to form. According to many experts land movement is not the leading cause for rupture instead "Stress corrosion cracking (SCC) is one of the leading causes for failure of underground pipelines." [17] There are many different types of SCC that are caused by different triggers. The different types of SCC include: Transgranular Cracking, which "occur on the external pipe surface exposed to groundwater with near-neutral pH; Intergranular Cracking, which occurs "with high pH solutions penetrating the protective layer of the pipeline" [17].

Image 4.7: Black and yellow waxy crude produced in the Uinta Basin [3].

SCC has been studied for many years and the development of SCC in pipelines has been broken down into stages: "(1) the establishment of the corroding environment on the external pipe surface in the coating-disbonded region where steel is susceptible to SCC, (2) the crack initiation; (3) the small crack propagation accompanying with crack initiation; (4) the main crack growth and (5) the pipe failure" [17]. Unfortunately the only part of the process that can be prevented is the contact that steel will have with the corroding environment. The other parts of the process can only be stopped by looking at the pipe itself, which is expensive since the pipe is buried and is not easily be examined. The type of protective layer can

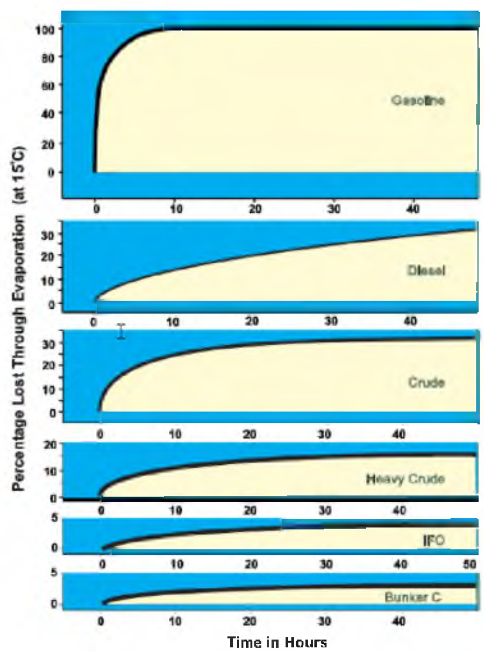


Figure 4.8: Oil evaporation curves [1].

have all the difference in delaying SCC; however, the word delaying is critical because even the smallest hole in the protective layer can start the SCC reaction.

4.5 Waxy Crude Spill Properties

Although it is difficult to predict the effects an oil spill will have on water surrounding the UEP, an examination of its chemical and physical properties, as well as past oil spills, are studied to determine potential risks.

Oil properties from one source are different than the properties of oil from another source; therefore, it is important to consider the specific characteristics of the crude oil that will be transported. The UEP will carry waxy crude from the Uinta Basin to Salt Lake City. One major issue with transporting the oil is its high pour point. The pour point is the temperature at which the waxy crude begins to solidify and become more viscous [19]. Waxy crude oils have high paraffin content, which increases the pour point because paraffin wax is solid at room temperature [20]. Although the high pour point creates pumping and other transportation problems, it is a beneficial characteristic during oil spills. The pipe is heated to allow the crude to flow, but once it is in the environment it will become semi solid and its viscosity will increase. Viscous oils do not spread as easily or penetrate the soil as rapidly [19]. At room temperature, the crude will not flow, which simplifies cleanup because solids are easier to handle and the crude affects a smaller area. However, more viscous oils are difficult to disperse yet the risk to groundwater is curtailed because the waxy crude can be removed before it penetrates the soil.

Other favorable properties of the waxy crude are its American Petroleum Institute gravity (API) as well as its insolubility in water. The API is a measure of the density of a petroleum product in comparison to water. If the API is greater than 10, the product floats. The API value of Black Wax Crude is 32, meaning it will not sink [21]. Also, based on its API value, black waxy crude is a light crude rather than a heavy crude. This high API value as well as insolubility, prevents the crude from spreading as quickly through the water, simplifying cleanup and lessening environmental impact. However, even if only a small amount of the waxy crude dissolves in the water, it can be toxic. Typical oil properties of gasoline, diesel and other oils are found in Appendix I. Light crudes have intermediate viscosity, density, solubility and API gravity values compared to the other oils listed in the table.

4.6 Weathering Processes

When oil enters the environment it undergoes weathering processes such as evaporation and emulsification. Crude oil evaporates more slowly than lighter petroleum products and evaporation slows down as time goes on with about 80% of evaporation during the first two days of the spill [19]. Since waxy crude is semi solid at temperatures below 99 degrees Fahrenheit, lower percentages of it evaporate and therefore cleanup is more difficult. Since the waxy crude is viscous, emulsification is less likely to occur. This is favorable because emulsification with water increases the volume of the spill. Emulsified oil is difficult to disperse because of its increased viscosity, and emulsion causes evaporation to slow and biodegradation to slow [19]. Natural dispersion will decrease the effort needed to clean oil. However, natural dispersion depends on the turbulence of water and is unlikely to occur in the rivers and lakes that the Uinta Pipeline is near.

4.7 Health Hazards of Waxy Crude

The black wax crude oil poses a health hazard if it comes in contact with the eyes or skin or if it is ingested or inhaled. According to the material safety data sheet of black wax crude oil, it “May cause severe eye irritation, conjunctivitis, skin irritation, defatting, dermatitis, nasal and respiratory tract irritation, central nervous system effects, possible secondary infection, anemia, irregular heart rhythm, behavioral changes, harmful or fatal if swallowed, gastrointestinal disturbance [22].” Also since the crude contains benzene, it may cause chromosomal damage and various blood diseases which can be fatal. Uinta black waxy crude has low amounts of sulfur compared to other petroleum products; however, even small amounts can be toxic [20]. It is a broad-spectrum poison that can affect several different systems of the body [22]. These health risks are not common issues that the public deals with after an oil spill because after the oil is cleaned up, the water is tested for safety. The toxic elements are usually present in low concentrations and the public is not exposed to them for prolonged periods. These health concerns are more applicable to those cleaning the spill and coming into direct contact with the crude oil. However, if the spill goes undetected for a long enough period it can become a concern for the public. According to the Utah Department of Environmental Quality, benzene exposure is the main concern immediately after an oil spill because it can move airborne [5]. However, it does not persist in the environment the exposure time is shorter and less likely to cause humans harm.

Even when a cleanup is deemed successful, there are possibilities that oil may still be present in the environment to cause issues. On June 12, 2010 oil from a Chevron Pipeline spilled into the Red Butte Creek near Salt Lake City, Utah. Looking at the spill and its effects is helpful when considering general issues that the Uinta Pipeline may cause to the public. Roughly, 800 barrels of medium crude oil spilled into the creek before the spill was detected. Of that, nearly 778 of the barrels were accounted for, and the water chemistry was analyzed after the spill to determine health hazards. Right after the spill, residents near the creek reported strong odors as well as related illnesses. However, by June 17, 2010 water quality tests showed that there was no immediate threat to human health [24]. More than two years after the spill, state water quality regulators announced that the Red Butte Creek was as clean as similar creeks that were not affected by the 2010 spill [24]. Critics argue that it is not clean and that the aquifer and creek will never be the same .They claim that the creek is permanently polluted because there are still trace amounts of oil-related compounds, but since there is no data about the levels of the compounds before the spill, it cannot be proven that they are from the spill [25]. After one year there was still residual oil in the Red Butte Creek that showed up in backwater areas, sediment and vegetation. Residents continued to report odors as well. Even after two years, oil remained in some areas along the creek bed and the aquatic organisms that were wiped out after the spill had still not fully recovered [25]. The oil degrades naturally and the health risks continue to decrease but as long as there is oil present, there are concerns for public health.

4.8 References

[1] P. Bolstad, GIS FUNDAMENTALS: A FIRST TEXT ON GEOGRAPHIC INFORMATION SYSTEMS, 4th ed., White Bear Lake, MN: Eider Press, 2012.

[2] Utah water research laboratory, “Weber River Watershed,” Great Salt Lake Information System, 2010.[Web]. [Accessed December 8, 2014].

[3] J. Payne, Summit County Agriculture Profile,” USU Economics Department, Vol. 25, no., pp., 2005. [Web]. [Accessed December 8, 2014].

[4] 1st Initial. Beehive history, “A Brief History of Morgan County,” Pioneer, Vol., no., pp., 2014.[Web]. [Accessed December 8, 2014].

[5] 1st Initial. Department of agriculture - forest service, “Visitor Guide,” Ashley National Forest, Vol., no., pp., 2009. [Print]. [Accessed December 8, 2014].

[6] Utah travel industry, “Uinta Mountains,” Utah.com, Vol., no. , pp., 2014. [Web]. [Accessed December 8, 2014].

[7] Weber basin water conservancy district, "2013 Consumer Confidence Report”, wwww.weberbasin.com, Vol. 14, no., pp., February, 2014. [Web]. [Accessed December 8, 2014].

[8] U. S. Department of commerce, “2013 Census,” United States Census Bureau, Vol., no., pp., 2014. [Web]. [Accessed December 8, 2014].

[9] “Water Questions and Answers,” The USGS Water Science School, Vol., no., pp., October 23, 2014. [Web]. [Accessed December 8, 2014].

[10] Utah department of natural resources, “Weber River Watershed Management Unit Assessment,” Vol., no., pp., 2013. [Web]. [Accessed December 8, 2014]

[11] L. Crawford, “Uinta Express Pipeline,” 2014.

[12] Utah Department of Water Quality, “Little Dell Reservoir,” Salt Lake City, UT, Aug. 2000.

[13] PG&E Fields Questions about Pipeline Rupture [Picture]. Available: http://www.bakersfieldcalifornian.com/business/x1766489196/PG-E-fields-questions-about-pipeline-rupture.

[14] Utah geological survey [Picture]. Available: www.geology.utah.gov /utahgeo/hazards/eqfault/.

[15] J. Zhang, Z. Liang, and C. J. Han, "Buckling behavior analysis of buried gas pipeline under strike-slip fault displacement," Journal of Natural Gas Science and Engineering, vol. 21, pp. 921-928, 2014.

[16] Bartlett, Steven F. "Protecting Pipelines from Earthquakes." 2012 News Archives. University of Utah. 02 Oct. 2012. Web. 08 Jan. 2013. http://unews.utah.edu.

[17] B. T. Lu, "Further study on crack growth model of buried pipelines exposed to concentrated carbonate-bicarbonate solution," Engineering Fracture Mechanics, vol. 131, pp. 296-314, 2014.

[19] Fingas, Mervin. (2011, September 8). Oil Spill Science and Technology- Prevention, Response, and Cleanup. [Web] Elsevier. Available: http://app.knovel.com/hotlink/toc/id:kpOSSTPRC2/oil-spill-science-technology/oil-spill-science-technology [Dec. 7, 2015].

[20] Deo, Milind. Black Wax Issues [Online]. Available: http://www.coqa-inc.org/docs/default-source/meeting-presentations/20110609_Deo.pdf.

[21] Filden, Sandy. "Handling Expanding Uinta Basin Crude Production." Internet: https://rbnenergy.com/do-ya-think-i-m-waxy-handling-expanding-uinta-basin-crude-production, Oct. 26, 2013 [Dec. 7, 2014].

[22] "Material Safety Data Sheet: Black Wax Crude Oil." Internet: http://silvereaglerefining.net/wp-content/uploads/2011/07/ser05.pdf, Apr. 7, 2004 [Dec. 7, 2014].

[23] "Red Butte Creek Oil Spill: Frequently Asked Questions." Internet: http://www.deq.utah.gov/locations/R/redbutte/faqs.htm, [Dec. 7, 2014].

[24] Lambert, Mcdaniel. "Human Health Risk Assessment: Red Butte Creek." Internet:http://www.deq.utah.gov/locations/R/redbutte/docs/2012/11Nov/Final%b20HHRARedButteCreek110512.PDF, Nov. 2012 [Dec. 7 2014].

[25] O'Donoghue, Amy. "Two Years after spill, Red Butte Creek safe." Internet: http://www.ksl.com/?nid=960&sid=21220914, Jul. 12, 2012 [Dec. 7, 2014].

Appendix I: Tables

Table 4.1: Regulated Inorganic Contaminants.

REGULATED INORGANIC CONTAMINANTS

Weber Basin NORTH - This data is derived from samples collected from 2006 through 2013.

Contaminants (units)	Average	Range Low	Range High	MCL	MCLG	Typical Source
Arsenic (ppb)	0.6	ND	1.2	10	NA	Erosion of natural deposits; runoff from orchards
Barium (ppm)	0.07	0.05	0.097	2	2	Erosion of natural deposits; discharge of drilling wastes
Total Chromium (ppm)	0.0004	ND	0.001	0.2	0.1	
Fluoride * (ppm)	0.1	0.1	0.2	4	4	Erosion of natural deposits
Nitrate (ppm)	1.0	0.3	1.9	10	10	Runoff from fertilizer use; erosion of natural deposits
Selenium (ppb)	0.7	0	1.2	50	50	Erosion of natural deposits; discharge from mines
Sodium (ppm)	13.4	12.5	14.3	NA[1]	NA	Erosion of natural deposits
Sulfate (ppm)	9.8	5	16.5	1,000[2]	NA	Erosion of natural deposits
Total Dissolved Solids (ppm)	209	188	249	2,000[2]	NA	Erosion of natural deposits

Weber Basin CENTRAL - This data is derived from samples collected from 2006 through 2013.

Contaminants (units)	Average	Range Low	Range High	MCL	MCLG	Typical Source
Antimony (ppb)	0.6	ND	0.6	6	6	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic (ppb)	0.6	ND	1.2	10	NA	Erosion of natural deposits; runoff from orchards
Barium (ppm)	0.15	0.08	0.26	2	2	Erosion of natural deposits; discharge of drilling wastes
Fluoride[4] (ppm)	0.71	0.4	1.1	4	4	Erosion of natural deposits
Nitrate (ppm)	0.5	0.12	1.6	10	10	Runoff from fertilizer use; erosion of natural deposits
Selenium (ppb)	1.1	0.6	2.1	50	50	Erosion of natural deposits; discharge from mines
Sodium (ppm)	32.0	13.9	61.5	NA[1]	NA	Erosion of natural deposits
Sulfate (ppm)	31.6	12	59	1,000[2]	NA	Erosion of natural deposits
Thallium (ppb)	0.6	ND	1.0	2	0.5	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories
Total Dissolved Solids (ppm)	372	315	416	2,000[2]	NA	Erosion of natural deposits

Weber Basin SOUTH - This data is derived from samples collected from 2006 through 2013.

Contaminants (units)	Average	Range Low	Range High	MCL	MCLG	Typical Source
Arsenic (ppb)	0.5	0	1.1	10	NA	Erosion of natural deposits; runoff from orchards
Barium (ppm)	0.08	0.06	0.1	2	2	Erosion of natural deposits; discharge of drilling wastes
Total Chromium (ppm)	0.003	ND	0.01	0.1	0.1	
Fluoride[4] (ppm)	0.7	0.5	0.9	4	4	Erosion of natural deposits
Nitrate (ppm)	0.7	0.15	3.4	10	10	Runoff from fertilizer use; erosion of natural deposits
Selenium (ppb)	1.3	0.001	3.3	50	50	Erosion of natural deposits; discharge from mines
Sodium (ppm)	33	13.7	80	NA[1]	NA	Erosion of natural deposits
Sulfate (ppm)	28.2	10.2	45.7	1,000[2]	NA	Erosion of natural deposits
Thallium (ppb)	0.2	ND	0.7	2	0.5	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories
Total Dissolved Solids (ppm)	361	290	432	2,000[2]	NA	Erosion of natural deposits

1) The State of Utah requires monitoring for sodium even though no MCL has been established.
2) The MCL for sulfate and total dissolved solids is established by the State of Utah.
3) This value represents naturally occurring llouride consentrations.
4) Fluoride levels in Davis County have been adjusted to an optimal level of 0.7 ppm.

*** The District does not add fluoride to water deliverd to Weber County**

Table 4.2: Regulated Organic Contaminants.

REGULATED ORGANIC CONTAMINANTS - Disinfection Byproducts

Weber Basin CENTRAL - This data is derived from samples collected in 2013.

Contaminants (units)	LRRA[1]	Range[2] Low	Range[2] High	MCL	MCLG	Typical Source
Total Trihalomethanes (ppb)	33.8	4.8	38.4	80	NA	By-product of drinking water chlorination
Haloacetic Acids (ppb)	18.3	0	23.1	60	NA	By-product of drinking water chlorination

Weber Basin SOUTH - This data is derived from samples collected in 2013.

Contaminants (units)	LRRA[1]	Range[2] Low	Range[2] High	MCL	MCLG	Typical Source
Total Trihalomethanes (ppb)	21.7	12	34	80	NA	By-product of drinking water chlorination
Haloacetic Acids (ppb)	16.6	6.6	25.2	60	NA	By-product of drinking water chlorination

1) This value represents the maximum location running annual average at the end of 2013.
2) Values in the "Range" columns are actual concentrations measured in ppb and reflect the range of detected levels.

REGULATED RADIOLOGIC CHEMICALS

Weber Basin CENTRAL - This data is derived from samples collected from 2006 through 2013.

Contaminants (units)	Average	Range Low	Range High	MCL	MCLG	Typical Source
Gross Alpha Particles (pCi/L)	3.0	2.7	3.6	15	0	Erosion of natural deposits
Combined Radium (pCi/L)	0.7	0.6	1.0	5	0	Erosion of natural deposits

Weber Basin SOUTH - This data is derived from samples collected from 2006 through 2013.

Contaminants (units)	Average	Range Low	Range High	MCL	MCLG	Typical Source
Gross Alpha Particles (pCi/L)	5.8	3.2	8.3	15	0	Erosion of natural deposits
Combined Radium (pCi/L)	1.0	0.5	2.4	5	0	Erosion of natural deposits

REGULATED MICROBIOLOGICAL CONTAMINANTS

Weber Basin CENTRAL

Contaminant	Percentage	Average	High[3]	MCL
Turbidity (Weber South WTP)	100%[2]	0.03 NTU	0.08 NTU	0.3 NTU
Turbidity (Davis North WTP)	100 %[2]	0.04 NTU	0.08 NTU	0.3 NTU

Weber Basin SOUTH

Contaminant	Percentage	Average	High[3]	MCL
Turbidity (Davis South WTP)	100 %[2]	0.04 NTU	0.08 NTU	0.3 NTU

1) This value represents the highest percentage of positive samples collected within the distribution system in any one month during 2013.
2) This value represents the lowest monthly percentage of combined filter readings meeting less than 0.3 NTU in at least 95% of the measurements taken each month during 2013.
3) This value represents the highest single measurement of combined filter readings taken every four hours during 2013.

Table 4.3: Typical Oil Properties.

TABLE 3.3 Typical Oil Properties

Property	Units	Gasoline	Diesel	Light Crude	Heavy Crude	Intemediate Fuel Oil	Bunker C
Viscosity	mPa.s at 15°C	0.5	2	5 to 50	50 to 50,000	1000 to 15,000	10,000 to 50,000
Density	g/mL at 15°C	0.72	0.84	0.78 to 0.88	0.88 to 1.00	0.94 to 0.99	0.96 to 1.04
Flash Point	°C	−35	45	−30 to 30	−30 to 60	80 to 100	>100
Solubility in Water	ppm	200	40	10 to 50	5 to 30	10 to 30	1 to 5
Pour Point	°C	NR	−35 to −10	−40 to 30	−40 to 30	−10 to 10	5 to 20
API Gravity		65	35	30 to 50	10 to 30	10 to 20	5 to 15
Interfacial Tension	mN/m at 15°C	27	27	10 to 30	15 to 30	25 to 30	25 to 35
Distillation Fractions	**% distilled at**						
	100°C	70	1	2 to 15	1 to 10	–	–
	200°C	100	30	15 to 40	2 to 25	2 to 5	2 to 5
	300°C		85	30 to 60	15 to 45	15 to 25	5 to 15
	400°C		100	45 to 85	25 to 75	30 to 40	15 to 25
	residual			15 to 55	25 to 75	60 to 70	75 to 85

NR = not relevant

Appendix II: Figures

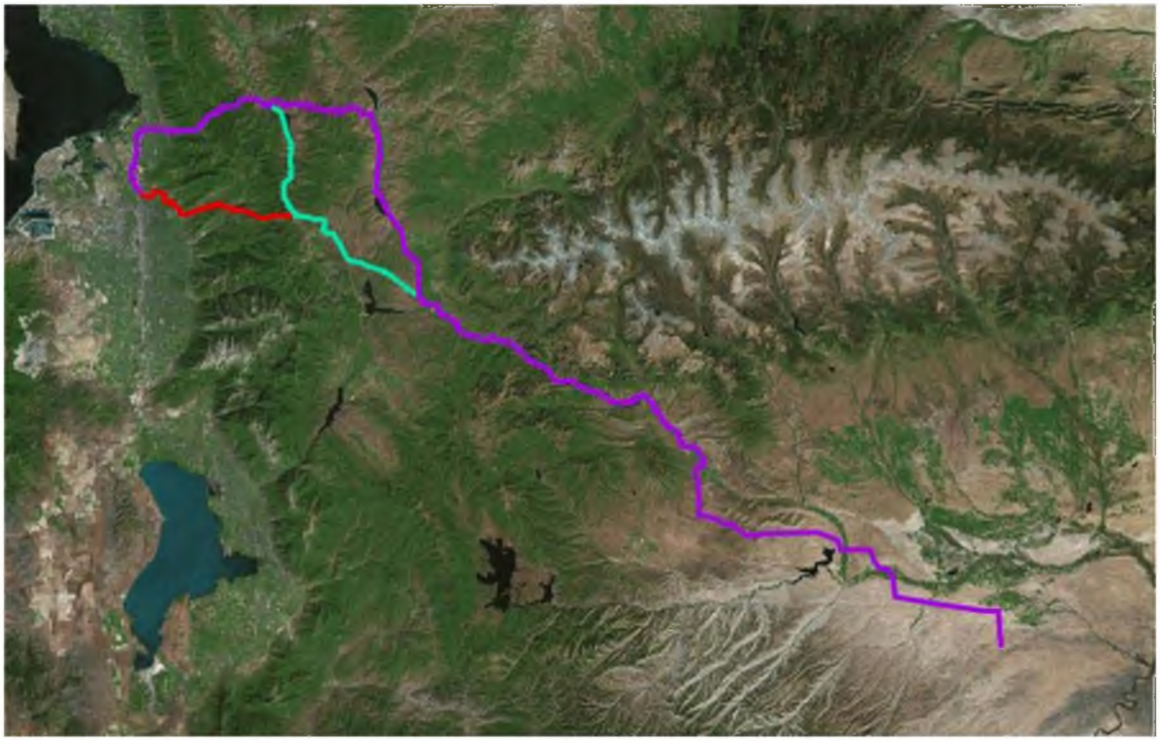


Figure 4.9: Proposed Routes.

Chapter 5

Front End Production

Abstract

This chapter covers the front end of extracting waxy crude oil from the Uinta Basin. General oil geology discussed and how it relates to the Uinta Basin. Pumperjack rigs and rotary rigs are used to drill horizontally and access the oil. Yellow waxy crude is found in the Wasatch Formation and the black waxy crude is found in the Lower Green River formation. These waxy crude oils are is what will be pumped through Uinta Express Pipeline. These oils are classified as Class B, light, and sweet crude oils with high pour points. The high pour point means that the oils cannot flow freely by themselves until they reach that temperature. Additives are effective at lowering the pour point. However the composition of the oil controls how effective additives are.

5.1 Introduction

Crude oil is a natural mixture of hydrocarbons, generally in the liquid state. Crude oil generally includes compounds such as sulfur, nitrogen, oxygen, and metals. Crude oil is important because it can be made into gasoline, diesel, or kerosene. Other by-products include fertilizer, soap, and plastics. Currently crude oil is the largest energy source on the world. Until energy sources are improved or new sources are found then crude oil will be extracted and refined for energy use.

5.1.1 Oil Geology

Oil is formed within Earth's crust from decaying organic matter. A temperature window of between 150°F to 300°F is required to form oil [1, pp.150]. These temperatures only exist after passing 7,000 feet below the surface meaning the organic matter that generates oil is millions of years old. After 18,000 feet if the temperature is too high gas or graphite will form from organic material instead of oil. The depths with acceptable temperatures to generate oil are referred to as the oil window [1, pp.151]. Heavier oils form at lower temperatures meaning and are generated closet to the surface and light oil is formed further down.

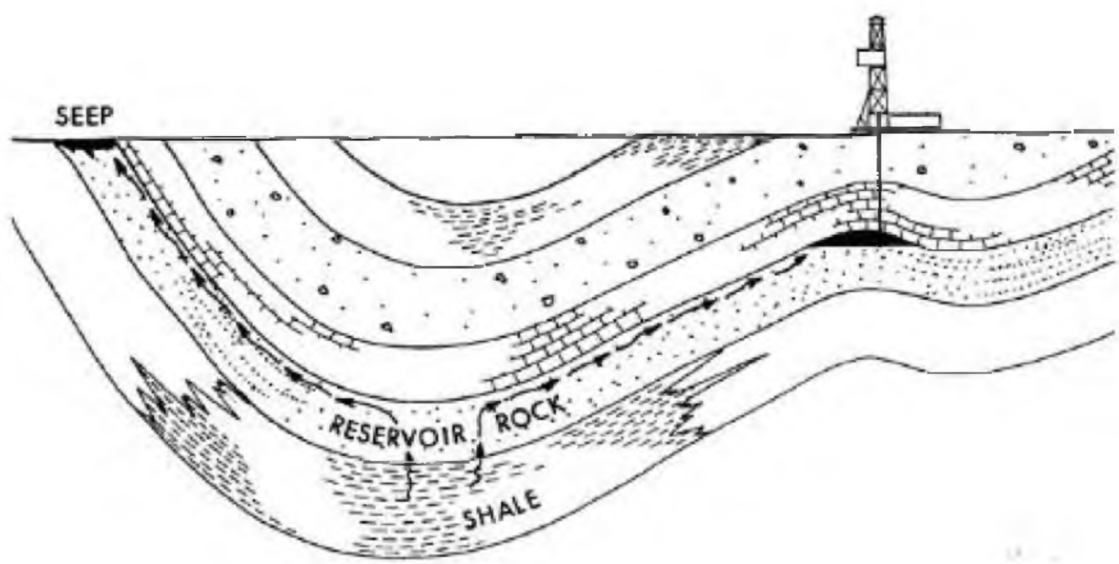


Figure 5.1: Formation of Oil [1].

Organic materials generate crude oil by changing from solid to liquid in a process that increases the original volume of solidus material. This increases the stress in the surrounding rocks and creates cracks for the new oil to travel upward through. Oil travels upward because it is less dense than the surrounding ground water. It reaches the surface and “seeps” through the ground, is lost in sediments, or is collected under impervious rock in a “trap”. On average only 10% becomes trapped or reaches the surface [1, pp.153]. The other hydrocarbons do not escape from the rock they are formed in or are lost while traveling upward. The percentage that becomes trapped is referred to as reserves or oil reservoirs. Within reserves liquids separate by density with gas on top, oil in the middle and salty water on bottom.

5.1.2 Uinta Basin Geography and Geology

The Uinta Basin is located south of the Uinta Mountains and north of the Book Cliffs of the San Rafael Swell. East and west of the basin are Douglas Creek Arch and the Wasatch Mountains, respectively. The Green River flows south through the middle of the basin. The basin’s geology has an even uplift of geologic formations, which become closer to the surface in the southern basin due to the San Rafael Uplift.

The basin contains large amounts of black and yellow crude oil reserves located between 1,300-18,000 feet below the surface [2]. The oil reserves are in the Green River and Wasatch Formations that formed in the Paleocene and Eocene time periods between 65 and 40 million years ago [3]. The oil itself has formed from organic matter over hundreds of millions of years.

The reserves of the basin are located in the northern Altamonut-Bluebell and southern Monument Butte regions of the basin with large gas reserves and smaller scattered oil reserves in the eastern regions of the basin as can be seen in Figure 5.2. Black waxy crude is typically what is found in the Green River formation in the Monument Butte reserves. Yellow waxy crude is found beneath this formation in the Wasatch Formation, or the Colton/ Flagstaff reservoir in the Bluebell reserves, though black and yellow crude can be found in either region [4].

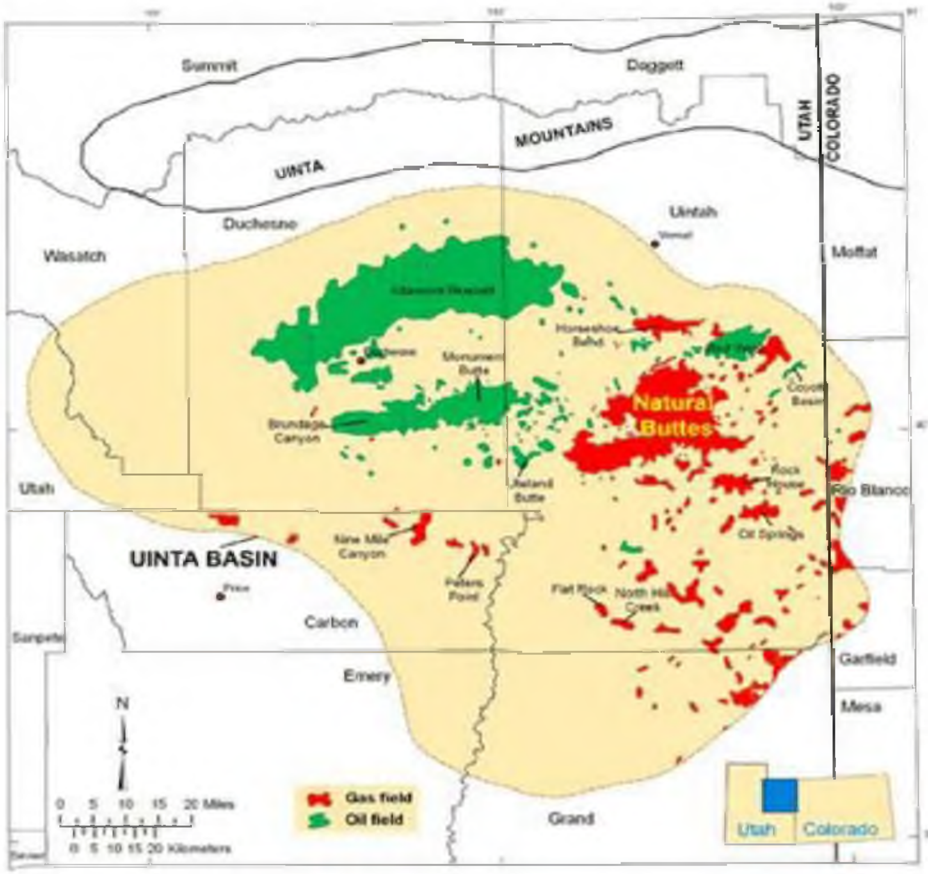


Figure 5.3: Oil and Gas in the Uinta Basin [6].

5.1.3 Mapping of Reserves

Seismic surveys are typically used to find and map oil reserves. They are performed by placing a series of sensors on the surface of the ground around a source of vibration. Vibrations are created from an explosion or vibrating truck. Shock waves travel from the source through the Earth's crust and reflect back to the surface differently depending on the properties of the object they reflect off. The reflected waves are recorded on the surface. The variations in the intervals between the waves are used to create the seismic map. Reserves will appear have a distinct pattern on the map that differs from other objects [5]. Seismic surveys have been conducted in the Uinta Basin around known oil sites to better find the sources [3]. The map in Figure 5.3 shows the main locations were oil is located in the regions of high waxy crude production.

5.1.4 Drilling and Extraction

Oil Wells are locations were oil is extracted from the Earth for use. There are three methods of extracting oil at an oil well: straight hole, extended reach, and horizontal drain well [7, pp. 285]. These methods all refer to differences in the path of the pipe used to extract the oil from within the Earth. Straight hole wells drill straight down and have little variation in direction of the pipe. Extended reach wells, or deviated, pipes angle from the well and travel at an angle extending to reserves located miles horizontally from the well site. A horizontal drain well consists of a straight hole pipe that has several pipes extending from the vertical pipe horizontally over long horizontal distances inside of large reserves.

The Uinta Basin consists mainly of horizontal wells spaced around 80 and 160 acre spacing [8]. A map of a region in the Bluebell field can be seen in the Figure 5.4 showing well spacing for oil production in the region.

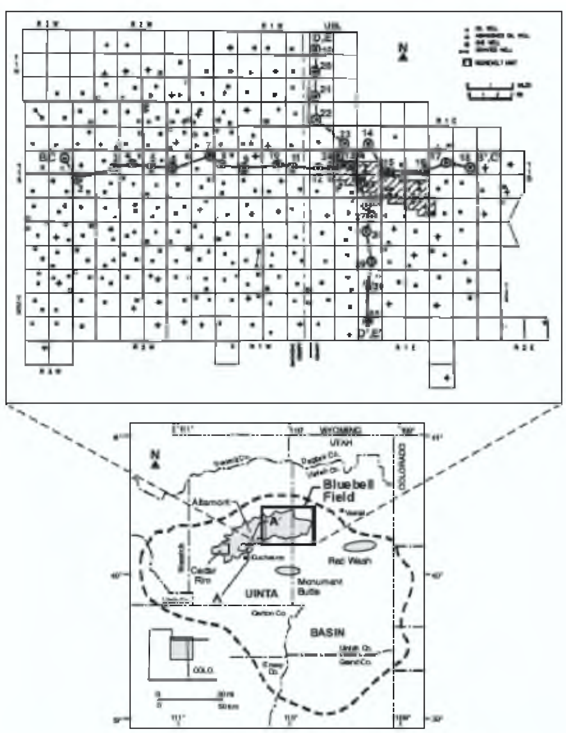


Figure 5.4: Map of Well Spacing in Uinta Oil Field [4].

Before oil wells are constructed over a potential oil field, an exploratory or wildcat well is built to test the potential for oil drilling [9, pp.241]. The well could be used to test if a potential reserve will produce oil or to test the extent of a reserve by being built further away from existing oil wells. If the test well produces oil, a process called logging is used to determine the extent the reserve. A "log" or vibrating tube is lowered through well into the reserve and from the reflected vibrations a 3D model can be made of the reservoir and oil flow properties determined [10].

Once the extent of the oil field is established after seismic mapping and well testing, oil wells can be established. Oil wells are drilled using a rotating drill head that is lowered from a drill rig, either built where the oil rig will be built later or by a vehicle mounted rig depending on the well size and type discussed later. The drill head has a motor attached to the back of the head and is attached to a pipe assembly that transports crushed rock and mud up to the surface [11, pp. 259]. The assembly is lowered using into the earth to create a borehole and drilling mud is pumped behind the drill assembly outside the piping to prevent a blowout. A well blowout is when a region in the earth that contains water, oil or gas at higher pressure than the surface create a rapid decompression causing the liquid or gas to rush to the surface in a geyser effect [12, pp. 280].

Blowouts are dangerous and the mud evenly distributes pressure by filling any void space in the borehole with liquid. A cap is placed over the borehole to further stop a blowout from causing damage if one occurs, and the mud is pumped through the caps "rathole" [13]. Once the drill head reaches a certain depth it raised and a pipe casing is lowered into the borehole and a cement mixture is piped through the middle to the bottom and back up around the outside of the pipe and the borehole to create a cement casing to around the extraction pipe that is lowered in after the casing is hardened. This is done is stages of around 4000 feet until reaching the oil reservoir [13]. The cement casing is created through the entire reservoir to the layer of sediment below and the extraction pipe is lowered to the bottom.

A device is lowered in the piping and concrete casing that creates holes in the pipe the concrete casing at the reservoir using explosives, allowing the oil to travel into the extraction pipe. After the holes are made the oil the drillers must “frac” the well or fracture the oil in order to allow it to flow into the pipe for extraction [14]. Water and sand are pumped in at high pressures to fracture the oil within the reservoir and create paths for the oil to flow through. Oil then seeps into these paths and flows to the source of the fractures at the well pipe and is drawn upwards. A “Christmas tree” or a series of valves that cap the pipe at the surface allow the oil to be extracted from the pipe without exposing the well pipe to atmospheric pressures. At this point a rig can be build over the well to extract the oil [15].

There are two types of oilrigs used in the Uinta basin: Pump Jack rigs and, Rotary Drill rigs. An example of a Rotary Drill rig can be seen in Figure 5.5. A Pump Jack can be seen in Figure 5.7 in Section 5.1.5. Both work similarly, at the bottom of the extraction tube a piston is drawn up and down via a hoisting line causing oil in the pipe to be drawn up on the upstroke and oil to be sucked in the pipe on the down stroke. In cases where more oil is drawn up or from deeper reservoirs the load on the piston supported by the rig is greater [11, pp. 250]. In these cases Rotary Drill rigs are better suited. Pump Jacks are less powerful and produce less oil but are less expensive. The type of rig used for a well depends on the amount of oil that can be produced and the profit that can be generated. Rotary drill rigs typically cost around $7.6 million dollars to construct [16]. Around $4 million of the total cost is spent on drilling and fracking, $2 million on leasing (discussed below) and $1.6 million on rig and cite construction [16]. Pump jack rigs cost between $100,000-$500,000 to construct depending on the size [17]. The amount of oil produced depends on the rig size and the well piping size and can vary from as low as 20 barrels per day to as much as 500 barrels per day [18].

Figure 5.5: Rotary Oil Wells [19].

Land mused first be leased to drilling companies through the Bureau of Land Management (or BLM). As of August 2011 the BLM have leased land for the construction of over 15,000 wells in the Uinta Basin as can seen in Table 1 below [20]. Once leased a permit must be acquired from the Utah Division of Oil, Gas, and Mining before drilling. Once the land has been leased and drilling and construction permits have been acquired drilling, site and rig construction can begin.

Table 5.1: Land Leases for Wells in Uinta Basin [20].

Well Code	Well Status	Count
Productive Wells		
P	Producer	7,997
S	Shut-in	926
TA	Temp. Abandoned	113
Total Productive		9,036
Other Active Wells		
A	Active Service	1,054
APD	APD Approved	2,437
DRL	Drilling	495
I	Inactive Service	13
OPS	Drllg Ops. Suspended	91
Total Other Active		4,090
Abandoned Wells		
PA	Plugged & Abandoned	2,575
TOTAL		15,701

5.1.5 Treatment and separation

Hydrocarbons extracted from oil reserves consist of gas, oils, salty water, and solids from the reservoir or fracking. Upon extraction from oil wells the oil must be separated and stored before transportation to be refined. Long cylindrical tanks called separators are used to separate oil from the unwanted substances. Separators work by pumping the raw oil, gas, water and solids into the heated tank that keeps the oil liquefied at high pressures (between 20 and 1500 psi depending on the oil) where the substances diffuse and separate according to densities [21, pp.264]. The oil can be drained from the bottom the tank, filtered to remove water and other substances, and the air can be removed from the top of the tank seen in Figure 5.6. Oil is not totally separated from the other substances while travelling through a separator therefore they are generally used in series in order to better separate the oil from other substances [21, pp.264].

From the separators oil goes through a flow line to be stored in storage tanks where it is later transported to be refined. A schematic of a pump jack, separator and storage tank can be seen in Figure 5.7

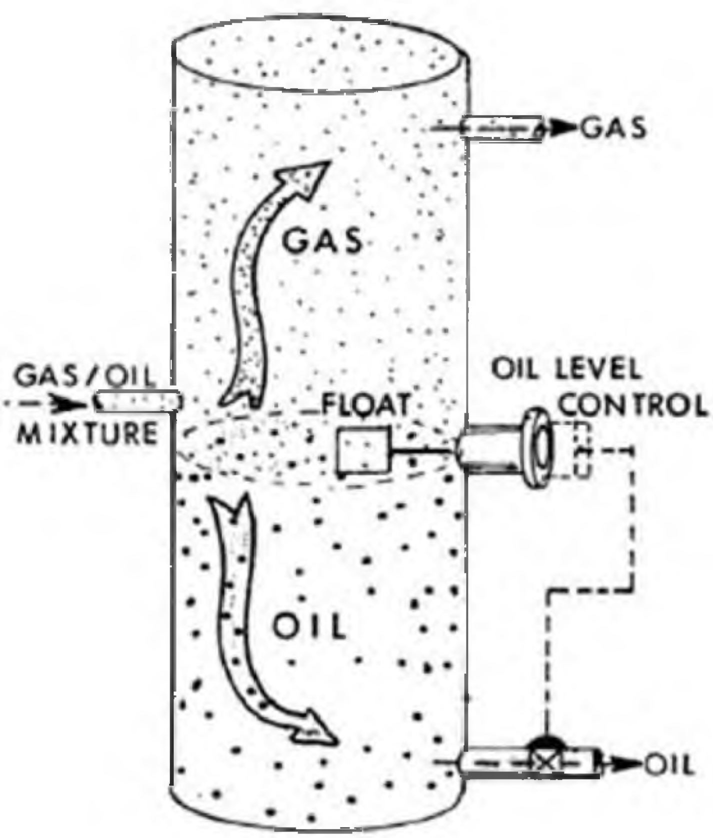


Figure 5.6: Oil Separation [21, pp.264].

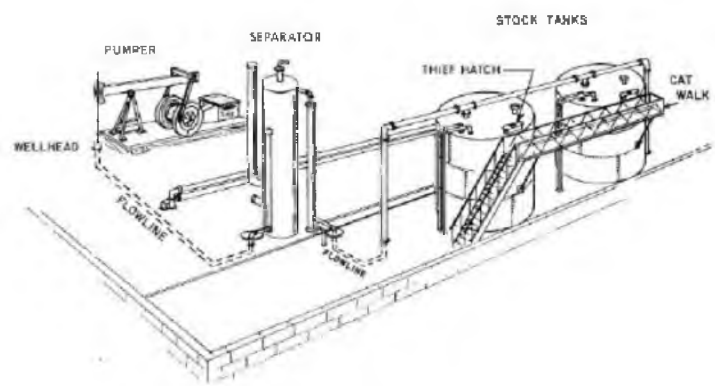


Figure 5.7 Oil Well Schematic [21, pp.372].

5.2 Classification

Crude oil comes in a variety of compositions and properties, which are observed between different oil fields and reserves. As seen in Table 5.2, a single reserve displays a wide array of boiling points. As boiling points increase the API Gravity decreases. The samples are taken from the same reserve but display different properties. The black and yellow waxy crude properties average test samples.

Table 5.2: Distillation Profile of Petroleum (Leduc, Woodbend, Upper Devonian, Alberta, Canada) and Selected Properties of the Fractions [22].

	Boiling Range °C	Boiling Range °F	Wt. %	Wt. % Cumul-ative	SG	API Gravity	Sulfur Wt. %	Carbon Residue (Conradson)
Whole Crude Oil				100	.828	39.4	.4	1.5
Fraction								
1	0-50	0-122	2.6	2.6	.65	86.2		
2	50-75	122-167	3	5.6	.674	78.4		

3	75-100	167-212	5.2	10.8	.716	66.1		
4	100-125	212-257	6.6	17.4	.744	58.7		
5	125-150	257-302	6.3	23.7	.763	54		
6	150-175	302-347	5.5	29.2	.783	49.2		
7	175-200	347-392	5.3	34.5	.797	46		
8	200-225	392-437	5	39.5	.812	42.8		
9	225-250	437-482	4.7	44.2	.823	40.4		
10	250-275	482-527	6.6	50.8	.837	37.6		
11	<200	<392	5.4	56.2	.852	34.6		
12	200-225	392-437	4.9	61.1	.861	32.8		
13	225-250	437-482	5.2	66.3	.875	30.2		
14	250-275	482-527	2.8	69.1	.883	28.8		
15	275-300	527-572	6.7	75.4	.892	27		
Residum	>300	>372	22.6	98.4	.929	20.8		6.6
Distill. loss				1.6				

The only way crude oil can be classified is by comparing its properties. The physical properties used to describe oil are specific gravity, American Petroleum Institute Gravity, and pour point. The most important chemical property is the sulfur level.

The specific gravity is the ratio of mass of a given volume of oil to the mass of an equal volume of pure water. This classification is important because petroleum is bought and sold on this basis or on a volume basis and then converted to mass using this relationship.

The American Petroleum Institute created API Gravity in order to show the quality between oils. Once other properties are known then the API Gravity can be used to approximate heat of combustion and hydrocarbon composition. The API Gravity is computed by the equation API = (141.5 / Specific Gravity of the oil at 60 degrees Fahrenheit) - 131.5 [22]. Specifically, the API gravity measures how heavy a petroleum is compared to water. When it is rated greater than 10 it can float on water and if it is rated less than 10 it sinks in water. A light crude oil has an API greater than 31.1, a medium crude oil has an API between 31.1 and 22.3 and heavy crude has an API between 22.3 and 10. Anything less than 10 is considered an extra heavy crude oil and will not float in water [22]. The pour point is an important physical property. When a substance reaches its pour point it will begin to show flow characteristics. Black waxy crude oil has a pour point of 105°F and yellow waxy crude has a pour point of 120°F[23]. This high pour point is the reason why the pipeline must be heated in order to transport the oil in fluid form.

The sulfur levels are important because when sulfur is emitted into the environment it can lead to plant corrosion and atmospheric pollution. Oils are considered cleaner when they contain lower sulfur levels. When an oil has less than .05% sulfur by weight it is classified as sweet and if it is above .05% by weight then it is considered sour [24].

Table 5.3: 1971 Utah Oil Sulfur Levels [24].

Area	Sulfur wt. %	Analysis Number	Formation	Depth (feet)	1971 Oil Production (Thousand Barrels)
Akah	.16	L6019R	Paradox	4688	10
Altamont	.17	B72034	Green River-Wasatch	12910	1131
Bluebell	.04	L68225	Green River, Lower	10359	1396
Bluff	.05	L60197	Paradox	5623	48
Boundary Butte	.11	L49071	Coconino	1498	451

Brennan Bottom	.11	L62042	Green River	5520	18
Bridger Lake	.05	L67134	Dakota	15764	841
Coyote Basin	.08	L68221	Green River	4419	59
Desert Creek	.11	L57040	Paradox	5244	14
Duchesne	.01	L55272	Wasatch	7518	30
Gothic Mesa	.05	L60193	Desert Creek	5768	43
Greater Aneth	.11	L57011	Paradox Lower (Hermosa)	5828	7860
Ismay	.05	L57012	Paradox Up (Hermosa)	5585	213
LISRON	.03	L60195	McCracken	8905	2604
Long Canyon	.07	L65009	Paradox lower	7050	16
MCELMO MESA	.10	L57139	Aneth (Hermosa)	5546	48
Monument Butte	.04	L68223	Green River	4916	36
PARIETTE BENCH	.27	L68139	None	4851	33
Recapture Creek	.10	L57038	Upper Hermosa	5354	70
Red Wash Area	.15	L62043	Green River	5550	5775
Roosevelt	.07	LS0337	Green River	9350	52
Salt Wash	.23	L67101	Leadville	8914	83
Tomonadla	.09	L60199	Paradox	5050	54

Agate	.61	L62037	Brushy Basin. Morpison	1562	7
Ashley Valley	.83	L50341	Weber	4181	265
Upper Valley	1.99	L62179	Kaibab	6060	1948

Table 5.4: Saudi Arabia Oil Sulfur Levels [3].

Area	Sulfur Wt. %	Analysis Number	Formation	Depth (feet)	1971 Oil Production (Thousand Barrels)
Abqaiq	1.30	B70063	None	None	325774
Abu Hadriya	1.69	B48005	Cretaceous	10000	37851
Damkam	1.54	B47053	None	None	7881
Fadhili	1.25	B70064	None	None	17474
Ghawar	1.85	B57009	Arab O. Clastic	None	781129
Khurais	1.73	B70068	None	None	8131
Abu Sa Fah	2.61	B70067	None	None	30289
Berri	2.24	B70070	None	None	56900
Khursaniya	2.54	B57006	Arab D. Clastic	None	27102
Manifa	2.75	B70069	None	None	1854
Qatif	2.55	B57018	Arab C. Clastic	None	34706
Safaniya	2.97	B67066	None	None	288853

Table 5.2 shows that the majority of Utah's crude oil was classified as sweet. This means that Utah's oil contains very little sulfur and will not affect the environment drastically. Table 5.3 show that all of the oils Saudi Arabia produces are considered sour. The amount of oil produced in Saudi Arabia accounted for 27.3% of foreign oil produced. As the major producer of crude oil, Saudi Arabia has very high sulfur content. In 1971, sulfur levels were

not a big factor and oil was refined as available. Today it is know that sulfur is the main component in Sulfur Dioxide (SO_2), which is present in acid rain. When humans are exposed to SO_2 they experience difficulty breathing and other respiratory issues. Since 1971 Saudi Arabian refineries have had to find ways to keep SO_2 from entering the environment. Crude oils with lower sulfur levels are less expensive; however, Utah's crude oil is more valuable because it contains low sulfur levels.

The Environmental Protection Agency (EPA) has defined crude oils based on toxicity, physical state, and changes that occur with time and weathering. Class A is light and volatile oils. These oils are highly fluid, often clear, spread rapidly on solid or water surfaces, have a strong odor, high evaporation rate, and are usually flammable [25]. Class B oils feel waxy, are less toxic, stick more firmly to surfaces, and contain medium to heavy paraffin levels [25]. Class C oils are heavy, sticky, viscous, and brown or black in color. They do not readily penetrate porous surfaces [25]. Class D is non-fluid oils, which are relatively non-toxic, do not penetrate porous substrates, and are usually black or dark brown[25].

Table 5.5: Black & Yellow Wax properties [23].

	Black Waxy Crude Temps in °Fahrenheit	Yellow Waxy Crude Temps in °Fahrenheit
API Gravity	42	32
Pour Point	120	105
BH Temperature	230	180

The waxy crude extracted from the Uinta Basin is designated Class B—light and sweet crude oil. Both types of waxy crude have approximately .01% sulfur content, very low acid content (Total Acid Number <.1), nitrogen content, and carbon residue. Low metal and sulfur content make refining waxy crude oil cleaner than other alternatives. The low metal content creates an excellent anode while the high paraffin content can be used for lubricant in heavy machinery. High paraffin levels are the reason these crude oils exert waxy properties and could act as cracker feed and bypass crude unit at certain refineries [23].

5.3 Waxy Crude Additives

Waxy crude has the characteristic of hardening under certain temperatures, which makes difficult to extract, produce, and transport. This has been a problem for a long time all over the world. The most common solution to these difficulties is to increase the waxy crude's temperature so it will flow constantly in a liquid phase. This issue has been approached from different views. One Particular view is that additives can reduce the waxy crude's cooling factors. Studies based on different percentages of additives and amounts of heat [26]. Additives in waxy crude does not only reduce cooling factors, but it is also more energy efficient, and reduces costs by a great deal.

The composition of waxy crude is very important because the melting point and additive needed to melt the waxy crude is determined from its composition. According to Norman Hyde in Nontechnical Guide to Petroleum, Geology Exploration, Drilling, and Production, having this additive and melting point keeps the waxy crude in liquid form and enables its transport via pipelines. Additives in this product are divided in three main groups of chemicals: wax inhibitors, wax crystal modifiers, and pour point depressant (PPD) [27]. These can reduce the growth of the wax crystal and form smaller crystals of a higher volume to surface ratio. Detergents and dispersants are primarily surface-active agents and act partly by modifying the surface of the pipe wall. By primarily keeping the crystals dispersed as separate particles it thereby reduces their tendency to interact with and adhere to solid surfaces (2001).

Wax crystal modifiers act at the molecular level to reduce the tendency of wax molecules to network and form lattice structures within the oil. Wax crystals modifiers prevent wax deposition, reduce oil viscosity and lower the wax gel strength are only effective when used continuously. Since they work at the molecular level, they are effective in concentrations of parts per million, as opposed to hot oil or solvents, which must be applied in large volumes [26]. Wax crystal modifiers have a high-molecular-weight and as a result, have high pour points, so their use is limited in cold climates.

There are different varieties of wax inhibitors which are based on the composition and purpose of waxy crude. Inhibitors like Alpha 5242 - 40%, 5482 - 73 to 77%, 5609 - 40% mostly vary by amounts of aromatic naphtha, toluene, and xylene for continuous or batch injection. This is normally applied at concentrations of 100 to 2000 ppm to crude above its crystallization point heated and mixed. There are also others inhibitors like Alpha 7526 - 40%, 7527 - 30%, 7527 - 30% which can also be diluted with heavy aromatic naphtha, diesel fuel, xylene, or alcohols for ease of handling [26]. Used in producing wells, oil handling and storage equipment, and in refineries.

Dispersants are a type of surfactants that helps disperse the wax crystals into the produced oil or water. This dispersing of the wax crystals into the produce oil or water helps prevents deposition of the wax and also has a positive effect on the viscosity and gel strength. Dispersants can help break up deposited wax into particles small enough to be carried in the oil stream. To prevent wax deposition dispersants must be used continuously and to remediate deposited wax, dispersants can be used continuously or in batch treatments. Dispersants generally have a very low pour point making their use suitable for cold climates. These chemicals are used in low concentrations and can be formulated in both aqueous and hydrocarbon solutions, making them relatively safe and inexpensive.

Para Clear® D290 - Contains synergistic blends of surfactants, amines, alcohols and diols not only penetrate and disperse the paraffin, but also isolate the paraffin molecules by forming a coat around them to inhibit their growth. Should be mixed at 3 to 10% in fresh water, pumped down the casing annulus, and be allowed to contact the paraffin for 12 to 24 hours [28].

SE-WD 5001 is a polymeric Wax Dispersant/ Inhibitor, which can lower the pour point of heavy waxy crude and other heavy fuels to control the deposition of wax in the downstream facilities of refineries, crude oil pipelines and other surface equipment. Aliphatic hydrocarbon waxes are present in most of crude oils. Wax precipitated from crude oil and deposits on internal wall of metal, which reduces diameter of pipelines, blocks valves or impedes production Equipment [27].

SE-AD 5002 is a Polymeric Carboxylic Ester based asphaltene dispersant, which can lower the pour point of heavy asphaltenic/ waxy crudes and other heavy fuels to control the deposition of asphalts/ wax in the downstream facilities of refineries, crude oil pipelines and other surface equipment. In Petroleum Geology of Brundage Canyon Oil Field Southern Tertiary Oil Trend, Unita Bas, Bruce Kelso and Jeffery Ehrenzeller argues asphaltene and wax are present in most crude oils. They precipitate and deposits on the internal wall of metal, which reduces diameter of pipelines, blocks valves, and impedes production.

The following tables 5.6 shows the effects of dispersive and detergents in the density, weight and deposits in the pipe at different temperatures of waxy crude. After these results, the evaluation shows that as temperature increases the weight of wax decreases and so do the deposits. By this false reasoning concludes that wax in a liquid form weight less than solid. When in reality crude oil has certain chemicals that can evaporate with extreme heat cause the waxy crude to weigh less than in a solid state.

Table 5.6: Effect of Dispersive and Detergents [26].

Temperature, °C	*Weight of Copper Tube, g*	*Weight of Wax Deposited, g*
60–15	282.9	10.5
55–15	283	10.6
50–15	283.7	11.3
45–15	284.5	12.1
40–15	284.9	12.5

5.3.1 Effects of Additives

Additives for the most part are effective in purpose. Some because of their chemical nature work better with other types of waxy crude. Effects take place in the polymer backbone, pendant chains, and molecular weight on cold flow performance. Wax control additives for crude oil are plagued by specificity. Specificity is exhibited when a cold flow package works only for a specific crude oil. Even slight changes in crude oil wax composition can cause reductions or total loss in performance.

Specificity arises from the interaction between the pendant chains of the wax control additives and the waxes present in the crude oil. The waxes in the crude are specific to the crude, but can and do change over time [29]. If the crude's characteristics change, i.e. the wax distribution changes, the wax control additive may no longer be well matched and pour point performance suffers. If the crude change is slight, an increase in the wax control additive treat rate often restores the performance but if the change is more significant, a change to a new wax control additive package may be needed to restore the pour point depression.

For the Pendant Chains, the interaction between the wax control additives and the paraffin in the crude oil is crucial and the additives work best when matched to the paraffin distribution in the crude. As the average carbon number of the pendant chain on the pour point depressant increases, the pour point of the additized crude drops until it reaches a minimum and then increases again. The article Petroleum Geology of the Brundage Canyon Oil Field, Southern Tertiary Oil Trend, Unita Basin, shows that PPD E’s average pendant chain length is most closely matched with the paraffin distribution in the crude and the greatest pour point depression results.

The polymer molecular weight of the wax control polymer may affect the interaction of the polymer with the paraffins. A very short, low molecular weight polymer may not have the molecular volume to disrupt the paraffin crystals as it co-crystallizes within the paraffin matrix. A very long, high molecular weight polymer may be so large that it interacts with itself instead of the crude oil paraffins or the polymer's solubility in the crude oil may be limited and actually initiate paraffin crystallization and thus raise the pour point of the crude oil [29]. Although the monomer may interact with the paraffins, the monomer's "molecular volume" is apparently too small to disrupt paraffin crystal formation.

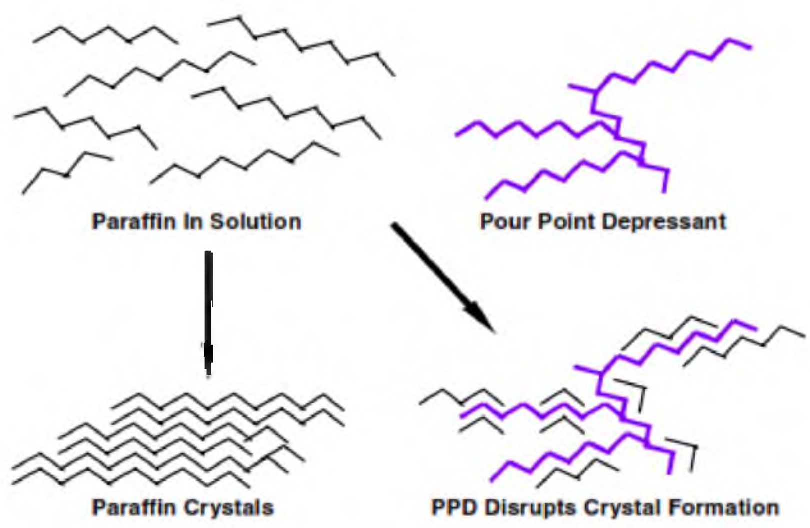


Figure 5.8: Idealized Mechanism Of Pour Point Depression.

All additives are quite effective in improving the flow properties especially when both elements are combined by additives and heat. The wax hardening increases with decreased ambient/ surface temperature. By further decreasing the temperature to pour point of oil or below, the deposition increases sharply. Also the most important variable to wax control performance is the identity of the polymer's pendant chains along with the interaction between the wax control additives and the paraffin in the crude oil is crucial and the additives work best when they are matched to the paraffin distribution in the crude [29].

5.4 Conclusion

Black and yellow waxy crude oil are in the Uinta Basin. Horizontal drilling is the main process used for extraction utilizing Pumperjack rigs and rotary drills. Black waxy crude oil is also found in the Lower Green River formation and yellow waxy crude is found in the Wasatch formation. Both have high pour points and are classified as Class B, light and sweet. In order to lower the pour points, additives may be added. These additives are effective depending on the oil’s chemical composition.

5.5 References

[1] Norman J. Hyne, "Source Rock, Generation, Migration, and Accumulation of Petroleum", Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production, 2nd Edition. Tulsa, OK. PennWell, 2001. pp. 149-66.

[2] Natural Gas Intelligence. "Information on the Uinta Basin," [Online]. Available: http://www.naturalgasintel.com/uintainfo [Accessed, November 27, 2014].

[3] John C. Osmond, "History of Oil and Gas Exploration in the Uinta Basin, Utah," The Mountain Geologist, Vol. 40, No. 4, October 2003. [Online].

[4] Craig D. Morgan, J. Wallace Gwynn, M. Lee Allison, Richard Curtice, Milind D. Deo, Richard Jarrard, Thomas H. Morris, Carol N. Tripp, "Characterization of the Bluebell Oil Field, Uinta Basin, Duchesne and Uintah Counties, Utah", Utah Geological Survey, Utah, SS-106, 2003. [Online].

[5] John McFarland, "How do Seismic Surveys Work?" April 15, 2009. [Blog Entry], Oil and Gas Lawyer Blog, Available: http://www.oilandgaslawyerblog.com/2009/04/how-do-seismic-surveys-work.html [Accessed, December 2, 2014].

[6] Utah Geological Survey, "Produced Water Management Tools, Uinta Basin, Utah", [Online]. Available: http://geology.utah.gov/emp/UBproduced_water/ [Accessed: December 2, 2014].

[7] Norman J. Hyne, "Drilling Techniques", Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production, 2nd Ed. Tulsa, OK. PennWell, 2001. pp. 285-96.

[8] Bill Barrett Corporation, "Uinta Oil Program", [Online]. Available: http://www.billbarrettcorp.com/operations/our-properties/uinta-oil-program/ [Accessed: December 2, 2014].

[9] Norman J. Hyne, "Drilling Preliminaries", Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production, 2nd Ed. Tulsa, OK. PennWell, 2001. pp. 233-46.

[10] San Joaquin Valley Geology, "Well Logs", [Online]. Available: http://www.sjvgeology.org/oil/logs.html [Accessed: December 4, 2014].

[11] Norman J. Hyne, "Drilling a Well – The Mechanics", Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production, 2nd Edition. Tulsa, OK. PennWell, 2001. pp. 247-72.

[12] Norman J. Hyne, "Drilling Problems", Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production, 2nd Ed. Tulsa, OK. PennWell, 2001. pp. 273-83.

[13] Kansas Geological Survey, "Petroleum Primer", pp. 12-15. [Online]. Available: http://www.kgs.ku.edu/Publications/Oil/primer12.html [Accessed: December 2, 2014].

[14] Earthworks, “Hydraulic Fracturing 101”, [Online]. Available: http://www.earthworksaction.org/issues/detail/hydraulic_fracturing_101#.VIjImWTiamE [Accessed: December 2, 2014].

[15] Meisa G, “The Differences Between a Wellhead and a Christmas Tree”, August 29, 2014, [Blog Entry]. C.R.O.F.T. Blog, Available: http://www.croftsystems.net/blog/the-difference-between-a-wellhead-christmas-tree [Accessed: December 2, 2014].

[16] Marcellus Drilling News, “How much does it Cost to Drill a Single Marcellus Well? $7.6 M”, [Online]. Available: http://marcellusdrilling.com/2011/09/how-much-does-it-cost-to-drill-a-single-marcellus-well-7-6m/ [Accessed: December 2, 2014].

[17] Petroleum Technology, “All Pumped Up – Oilfield Technology”, [Online]. Available: http://aoghs.org/technology/oil-well-pump/ [Accessed: December 2, 2014].

[18] U.S. Energy Information Administration, “Drilling Productivity Report”, [Online]. Available: http://www.eia.gov/petroleum/drilling/#tabs-summary-1 [Accessed: December 2, 2014].

[19] Adam Voge, “Plans for 23,000 Wells Buoy Wyoming’s Oil and Gas Future”, The Salt Lake Tribune, April, 1 2013, [Online]. Available: http://trib.com/business/energy/plans-for-wells-buoy-wyoming-s-oil-and-gas-future/article_f3d3ec28-41a5-566c-bde1-3009881dbe48.html [Accessed: November 27, 2014].

[20] Bureau of Land Management, “Greater Uinta Basin Oil and Gas Cumulative Impacts Technical Support Document”, [Online], Available: http://www.blm.gov/ut/st/en/info/newsroom/2012/march/greater_uinta_basin.html [Accessed: December 2, 2014].

[21] Norman J. Hyne, “Surface Treatment and Storage”, Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production, 2nd Ed. Tulsa, OK. PennWell, 2001. pp. 361-74.

[22] I. H. Khalaf, "Univesity of Technology Iraq," Chemical Engineering Department, 2009. [Online]. Available: http://www.uotechnology.edu.iq/dep-chem-eng/second%20year/Fuels%20Technology%20Dr.%20Intisar/lect1.pdf. [Accessed 7 December 2014].

[23] S. E. Nance, "Uinta Basin Update," Bill Barret Corporation, Denver, 2013.

[24] M. C. Jr., "Sulfur Content of Crude Oils," Bureau of Mines, Dallas, 1975.

[25] EPA, "Types of Crude Oil," EPA, Washington DC, 2014.

[26] V. Mahto, D. Verma, A. Kumar & V. P. Sharma (2014) Wax Deposition in Flow Lines Under Dynamic Conditions, Petroleum Science and Technology, 32:16, 1996-2003, DOI:10.1080/10916466.2012.733468.

[27] S. Deshmukh & D. P. Bharambe (2012) Wax Dispersant Additives for Improving the Low Temperature Flow Behavior of Waxy Crude Oil, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 34:12, 1121-1129, DOI: 10.1080/15567031003753587.

[28] El-Gamal, Ismail M., and Ahmed M. Al-Sabbagh. "Polymeric additives for improving the flow properties of waxy distillate fuels and crudes." Fuel 75.6 (1996): 743-750.

[29] Chou, Shang, and Curtis B. Campbell. "Oil recovery method for waxy crude oil using alkylaryl sulfonate surfactants derived from alpha-olefins and the alpha-olefin compositions." U.S. Patent No. 6,269,881. 7 Aug. 2001.

Chapter 6

Pipeline Design and Power Calculations

Abstract
This research project focuses on the Uinta Express Pipeline and its components. The proposed pipeline would begin in the Uinta Basin near Duchene, Utah, and travel northwest towards East Canyon until it turns west to connect to the Northern Salt Lake Tesoro refinery. The selected pipe has a 12-inch diameter and is made of carbon-steel. The pipe would be wrapped with HDPE pipe insulation and get heated to maintain waxy crude oil flow. The pipeline will potentially deliver up to 60,000 barrels of crude oil per day and will replace 250 truck-tankers from Utah highways. This project is in the preliminary phase, but its anticipated construction will begin in 2016.

6.1 Introduction: The Pipeline

This chapter analyzes the Uinta Express pipeline and its components including: the 12 inch inside diameter pipe, the pumps and pumping stations along the pipeline, pipeline heating element, and other fittings required to move the anticipated volume of waxy crude oil the required distance. Tesoro's exact system design and pipeline route is currently in the research and development stage, therefore this report makes generalized assumptions and estimates that are required in order to calculate the data needed to determine the quantity and size of pumps and also the energy that will be supplied to power the crude oil pipeline system. Four possible pipeline routes are proposed and environmental impact studies are still currently in progress therefore this study will analyze the 135 mile Northern Route proposed by Tesoro which was the preferred route at the time of this study.

6.2 Background: The Accident

Proponents of the Uintah pipeline suggest that as many as 250 oil tanker-trucks may be eliminated from Utah's highways creating a safer atmosphere for highway commuters and the local environment. A traffic accident occurred on April 30, 2014 involving a Tesoro oil tanker which spilled 4,500 gallons of Uinta Basin's crude oil in Salt Lake's Parleys Canyon [1]. Fortunately, the tanker did not harm nearby commuters and the crude oil was cleaned up quickly and did not contaminate local water ways. Tesoro's proposed pipeline would eliminate this type of accident from occurring on Utah's highways although constructing a pipeline through private and public lands does raise its own set of environmental liabilities. Nevertheless, this truck accident proves to support Tesoro's efforts to construct an oil pipeline—a trend which parallels the general movement in America for transporting oil products domestically. Currently, over 70% of all crude oil and petroleum products are transported across America by pipeline and there are thousands of additional miles of pipeline at different stages in the approval process nationwide to decrease the amount of oil hauled by tanker-trucks [2].

6.3 Terminology

The Tesoro oil refinery pipeline must accommodate up to 60,000 barrels of oil per day and will originate near Duchesne, Utah and terminate in northern Salt Lake City. Efforts were made to obtain the Tesoro technical specifications and the exact path of the pipeline, unfortunately Tesoro was not willing to distribute their engineering design files. Therefore, it was needed to be recreated using the Tesoro's screenshots as a guild posted on <http://uintaexpresspipeline.com/>. The path was redrawn using Google Earth for the ease in which elevation changes could be obtained. By this design it was determined that the 135 miles, 12 inch carbon-steel pipe must ultimately climb an elevation of over 9,600 feet through the Uinta National Forest [3]. The pipe will be buried a minimum of 3 feet in order to protect the pipeline from impacts, abrasions, corrosion, and to keep intact the original aesthetics of the surrounding environment. The operation pressure is expected to be 1,200 to 1,400 pounds per square inch (—).

6.3.1 Flow Rate

Pumps at the origination station and at each four auxiliary pumping stations will deliver energy to the waxy crude, which will increase the pressure allowing the crude to flow through the pipe. The pumps must deliver the required destination flow rate (Q) and also develop the required energy $\square h_{\square}\square$ in order to overcome the friction caused by the waxy crude's viscosity and the pipeline's system components. Pumps installed in series and in parallel (more on this in section 6.6) will be used at the origination station in Duchesne and at each of the four ancillary stations. The quantity of crude oil per time will have a volume flow rate ($\mathbf{Q}$) of 60,000 barrels per day which equates to 1,750 gallons per minute (—) or 29.2 gallons per second (—). In order to use the continuity equation ($\mathbf{Q} = \mathbf{AV}$) the units must be in the form cubic feet per second (—). Through unit conversion the flow rate is equal to 3.899 —. Volume flow rate is a function of the pipe's cross-sectional area ($\mathbf{A}$) and the velocity ($\mathbf{V}$) of the crude.

Assuming that the waxy crude is an incompressible fluid, pumped at a steady flow rate, and no fluid is added, stored, nor removed in-between auxiliary stations, the velocity is found by algebraically manipulating the continuity equation to the form $\mathbf{V} = \frac{\square}{\square}$. According to the U.S. Army Corps of Engineers' manual Liquid Process, the recommended range of flow velocities for normal liquid service applications should be in the range of 4-10 feet per second ($\frac{ft}{s}$) [4]. The discharge velocity for the crude oil is 4.963 $\frac{ft}{s}$. The flow rate, velocity, and pipe cross-sectional area are needed to determine pump size and to calculate the power needed to operate.

6.3.2 Energy and the Bernoulli's Equation

The waxy crude oil possesses three forms of energy, according to the conservation of energy law this energy cannot be created or destroyed, and therefore energy at the beginning of the pipeline must equal the energy at the end of the pipeline [4]. Potential energy, kinetic energy, and flow energy are the forms of energy that must be considered when analyzing the energy of the fluid in a pipeline. The sums of these energies must equal the total energy (E) therefore $E_{inlet} = E_{outlet}$. Potential energy (PE) is equal to the weight (w) of an element of oil multiplied by an elevation (z) relative to a reference elevation ($PE = wz$). Kinetic energy (KE) is derived from the crude oil's velocity, ($KE = \frac{wv^2}{2g}$), and g is the gravitational constant. Flow energy or pressure energy is the amount of work that is necessary to move fluid against pressure ($FE = \frac{wp}{\gamma}$) such that p is the pressure at a specific location and γ is the specific weight of the crude oil which is a property that is unique to each fluid and is determined by its density when compared to water.

Each term is divided by unit weight resulting in an expression for the energy possessed by the waxy crude oil per unit weight or in other words, head. This energy transfer correlation is referred to as the Bernoulli's equation. The resulting energy from inlet to outlet is in the unit of feet therefore a higher feet calculation means that the pumps must scale up to accommodate. The three forms of energy per unit weight are now pressure head ($\frac{p}{\gamma}$), the elevation head is z and the velocity head is $\frac{v^2}{2g}$. The total head or total energy is the sum of these three energies. Additional expressions can be used in Bernoulli's equation to account for energy losses due to friction from valves, fittings, bends in the pipe, and the roughness of the pipe walls. These expressions sum to equal the total energy lost also known as head loss (h_L) which is subtracted from the left side of the equation. Additionally, the expression for potential energy or total dynamic head that a pump must supply to the system is a term that may be added to the left side of Bernoulli's equation. This general form of Bernoulli's equation is used to analyze the pipeline system between two specific locations for sizing pumps.

$$\frac{p_{1}}{\gamma} + z_{1} + \frac{v_{1}^{2}}{2g} + h_A - h_L = \frac{p_{2}}{\gamma} + z_{2} + \frac{v_{2}^{2}}{2g}$$

This general equation is rearranged to find the head added (h_A) by the pump to the system. Data such as pressure, specific weight of the crude oil, elevation difference, pressure differences, velocity, and gravity may be either canceled or entered into the equation depending on circumstances and the equation is simplified as follows:

$$h_A = \frac{p_{2} - p_{1}}{\gamma} + (z_{2} - z_{1}) + \frac{v_{2}^{2} - v_{1}^{2}}{2g} + h_L$$

6.3.3 Head Loss by Pipeline Components

The pipeline, the system's components, and the viscosity of the flowing fluid cause head loss that the pump will need to counteract in order to create a steady flow rate of crude oil. The head loss in pipe fittings, valves, and other components are minor losses when compared to the head loss due to the pipes inside wall roughness. The generated head loss is calculated using the Darcy–Weisbach equation. Such that f is a friction factor unique to the pipe diameter and its roughness, L is the length of the pipe, D is the diameter of the pipe, v is the velocity of flow and g is the gravitational constant. These variables are related to head loss as follows:

$$h_L = f * \frac{L}{D} * \frac{v^{2}}{2g}$$

The energy loss in a fluid due to its viscosity is dependent on the type of flow that occurs in the pipe. To predict whether the flow is turbulent or laminar (non-turbulent) the Reynolds number (N_R) is calculated. The equation also uses velocity and pipe diameter but it also requires unique properties of the fluid that are experimentally determined including density (ρ) and dynamic viscosity (μ) which are related as follows:

$$Re = \frac{\rho V D}{\mu}$$

This Reynolds number is used in connection with relative roughness and pipe diameter to determine the friction factor f for turbulent flow from a Moody diagram which, in turn, solves for the head loss (h_f) of the pipe. In order to determine f first determine the ratio between pipe roughness and pipe diameter on the right y-axis and follow that line as it curves and intersects the calculated Reynolds number on the x-axis. At the point of intersection is the friction factor on the left y-axis. It was calculated by the Reynolds number that the flow in turbulent.

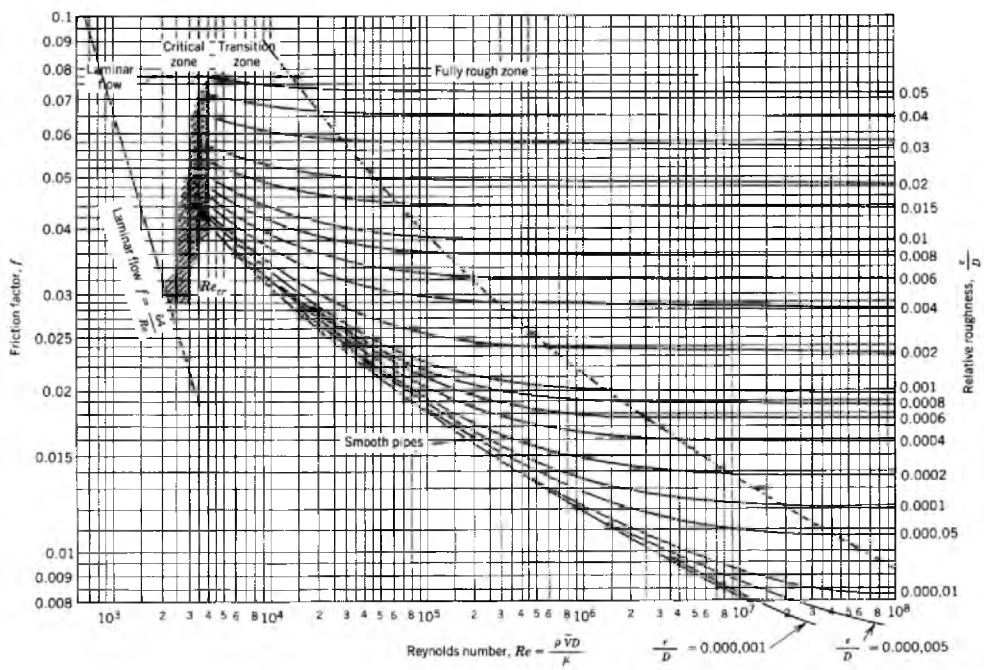


Figure 6.1: Moody Diagram: used to determine the friction factor for pipe length.

6.4 Calculating Head Loss

Assumptions must be made for the unknowns and estimates must be carefully determined in order to calculate the energy required to pump the crude oil to the refinery. The first stage of identifying the unknowns in the pipeline and all of its components is to acquire as much data on the project as possible. Elevation is a large energy loss that the pumps must work against to move the waxy crude oil. Gravitational forces act on the oil and the elevation head is increased due to the weight of waxy crude oil.

The Darcy–Weisbach equation in conjunction with the Bernoulli's equation is used for solving for head loss (h_f). Also the length of pipe needs to be in feet so simply multiply 135 miles by 5,280 feet per mile totaling 712,800 feet. By inserting all the known variables calculated earlier the head loss is as follows:

$$h_f = f * \frac{L}{D} * \frac{V^2}{2g} = 0.025\left(\frac{712,800}{1}\right)\left(\frac{4.96}{2 * 32.2}\right)^2 = 6,565\ \text{feet}$$

This result is the additional head that the pumps need to produce in order to overcome the friction resistance due to the texture of the pipe's inside walls. This calculation is based on a straight pipe with no elevation change. In order to compensate for the bends of the pipe and the various valves and cleanout access points, minor head losses, an additional calculation is required. These additional minor losses add up and must be accounted for but rather than counting every possible turn of the pipe and every valve and discontinuity along the 135 miles of pipeline, a simple scaling factor of 1.2 was implemented to radically simplify the calculation. This means that approximately an additional 20% would be added to the head loss to compensate for all the minor losses. Figure 6.2 describes the approximate locations of the pump stations along the pipeline. This map was created in Google Earth in order to know the elevation changes and distances between pump stations. The primary pump station is labeled #1 and the Tesoro refinery is #6 with additional pump stations in between, see the following satellite image locating the pipeline pump stations and refinery.

Figure 6.2: The Uinta Express Pipeline: Potential pump stations along the route.

Due to all the bending and additional fittings on the pipeline the total head loss inside the pipe including minor losses totaled 7,878 feet. This is just the first step in determining the overall head required by the pumps.

$$h_{L} = 6{,}565\ ft(1.2) = 7{,}878\ ft$$

6.4.1 Elevation Head

Another significant head loss is elevation head by using a part of the Bernoulli's equation $(z_{B} - z_{A})$. This calculation, pumping to a higher elevation, is the difference of elevation from point A to point B. This change of elevation varies from pump station to station and the pump design must change to accommodate for the variation in head loss (or gain). Through unique calculations between each section of pipe summed between pumping stations, it is determined that the net head is as follows:

Table 6.1: Pump Demands: Calculations bases on unique changes between stations.

Pipe Sections	Elevation Change ([illegible])	Distance Change ([illegible])	Distance Change ([illegible])	Head Loss (*h*[illegible])	Head Added (*h*[illegible])
1-2	1,380	24	126,720	1,443.3	2,823.3
2-3	2,854	26	137,280	1,563.6	4,417.6
3-4	-3,375	25	132,000	1,503.4	-1,871.6
4-5	479	35	184,800	2,104.8	2,583.8
5-6	-2,546	21	110,880	1,262.9	-1,283.1

Notice between Section 3-4 and Section 5-6 the decrease in elevation actually decreases the required head the pump needs and offsets the total head required for the whole pipeline. This is due to gravitational forces doing work on the crude oil which lessons the energy required by the pumps in these sections. Gravity will greatly increase the rate at which the oil will flow and thus reduce the power needed by the pump to push the fluid on. But in order to maintain a constant flow rate an increased back pressure is generated on the pump and must be addressed or the pump(s) will be damaged overtime. This back pressure can be alleviated by the use of gate valves. Therefore, periodical gate valves will be needed to decrease the pressure on the pump(s).

Next, the velocity head and pressure head losses are calculated by using another part of the Bernoulli's equation but this is assumed to equal zero since these values do not change from a particular point to the next. Therefore, the total head loss is the sum of the friction head loss including minor losses and elevation head loss. This total is equal to the head added by the pump (*h*[illegible]) or in other words, this is the head required by the pumps in order to compensate for the head losses occurred.

h[illegible] = 7,878 [illegible] 1,280 [illegible] 6,670 [illegible] *h*[illegible]

Head required by the pump can be used in the power equation ([illegible] = *h*[illegible]) when correlating work energy to power energy which can then be correlated to electricity, such that P_h is equal to the energy required by the pump to overcome the head losses, $h_{loss,total}$ is the total head losses, γ again is the unique specific weight of the material as it relates to water, and Q again is the volume flow rate. Therefore, the power required by the pump is as follows:

$$P_h = h_{loss,total}\,\gamma Q = 6,670\ ft\left(56.53\ \frac{lb}{ft^3}\right)\left(3.9\ \frac{ft^3}{s}\right) = 1,470,515\frac{ft \cdot lb}{s} = 2,674\ hp$$

$$= 1.994\ megawatts$$

6.5 The Pipe

The pipeline is 12″ carbon steel pipe, 0.375 WT (thickness of the steel), API 5L, X52, insulated in high-density polyethylene: jacketed (externally coated), and buried at a minimum depth of three feet. System pressure designs are currently projected to be between 1,200 and 1,400 psi maximum operating pressure [3]. Carbon-steel is used because it is durable, safe, and does not need to be treated with preservatives or glue; but it is selected largely in part for its high tensile strength. Fluctuating interior pressure or external shock pressure have little effect on this steel. Due to the conditions of the pipe's proposed route, it will encounter stress, which necessitates high tensile strength of the material thus providing additional elasticity and ductility to the pipe, even under high pressures. A carbon-steel pipe is highly resistant to shock and vibration and can be made much thinner than pipes made from other materials thus reducing the weight while maintaining desired pressure resistance and maintaining diameter. See Table 6.2 which describes the advantages and disadvantages of this type of pipe.

Figure 6.3: Carbon-steel pipe.

Table 6.2: Pros and Cons Comparison: Highlights advantages and disadvantages of carbon steel pipe.

Advantages	Disadvantages
High tensile strength	Prone to external corrosion
High compressive strength	Electrolysis prone
Range of corrosion protection systems	Jointing requires skilled welders
Wide range of diameters and wall thickness	Internal/external corrosion protection systems add to price
Welded joints give continuity	Coatings and linings can get damaged during installation and by third parties

6.5.1 Steel Pipe Properties

Figure 6.4: 12” Carbon-steel Pipe (Non-insulated).

The American Petroleum Institute specification API 5L covers seamless and welded steel line pipe. This is steel pipe meant for pipeline transportation systems in the petroleum and natural gas industries. API 5L is suitable for conveying gas, water, and oil. Grades covered by this specification are A25, A ,B (and the following "X" Grades), X42, X46, X52, X56, X60, X65, X70, X80. The two digit number following the "X" indicates the Minimum Yield Strength (in 1000 psi) of pipe produced to this grade. The following table further describes the mechanical properties of this carbon-steel pipe [5].

Table 6.3: Mechanical Properties: Carbon Steel.

	API 5L X52 (psi)
Tensile strength, min / max	66,700 / 110,200
Yield strength, min / max	52,000 / 76,900

6.5.2 High-Density Polyethylene

When choosing a type of insulated underground pipe it is important to consider several key points, such as; adequate insulation, climate, length and R values. Higher R values mean lower heat loss from point A to point B. The insulated underground piping should be continuous with no joints, couplings or unions between heat exchangers.

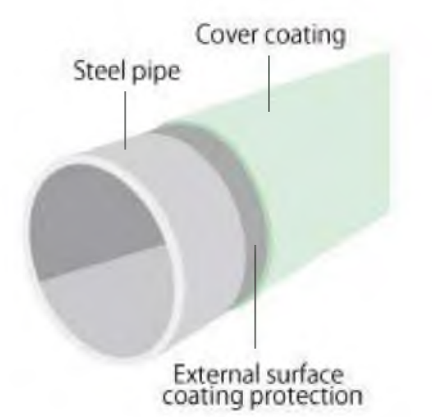


Figure 6.5: Pipe Coatings.

The purpose for high-density polyethylene as the coating is because of its large strength to density ratio. Its density is less than 1 gram per cubic centimeter, which allows for less weight being added to the steel pipe. Another reason for using high-density polyethylene is that it can withstand high temperatures (120 °C/ 248 °F, and for short periods, 110 °C / 230 °F continuously) [5].

6.5.3 Heating the Pipe

When a material is transported by pipeline at a temperature above its surroundings, it will lose heat. Insulation will slow the heat loss, but will not prevent it. Temperature can be maintained by adding heat to make up the loss. This can be accomplished in many different ways. Heating stations can be located along the pipeline to make up the loss at discrete points. The disadvantage with this technique is that the product does not stay at a uniform temperature, and if flow stops the product could lose a significant amount of heat that it becomes difficult to pump. Heat can be added along the entire length of the pipeline by applying a heater to the pipe. This is commonly called heat tracing. Heat tracing can be accomplished using many different techniques. Steam, hot oil, hot water, and electric heaters are all commonly used methods. Electric tracing can be further broken down into parallel heating cables, series heating cables, self-limiting heating cables, mineral insulated cables, impedance heating, and skin effect heating. Each method has advantages and disadvantages [6].

Heating the pipeline prevents freezing but more importantly it controls the viscosity of the crude. There are special requirements for electrical heat tracing because most situations require long electrical circuits. For the Uinta Express Pipeline, skin-effect heat trace is to be used to heat the pipe. Heating elements are placed along the length of the pipeline and can be turned on remotely as needed. An electrically insulated, temperature-resistant conductor is installed inside the heat tube and connected to the tube at the end. The tube and conductor are connected to an AC voltage source in a series connection. This method of heating is called skin-effect heating because the return path of the circuit current is pulled to the inner surface (1 mm) of the heat tube [6].

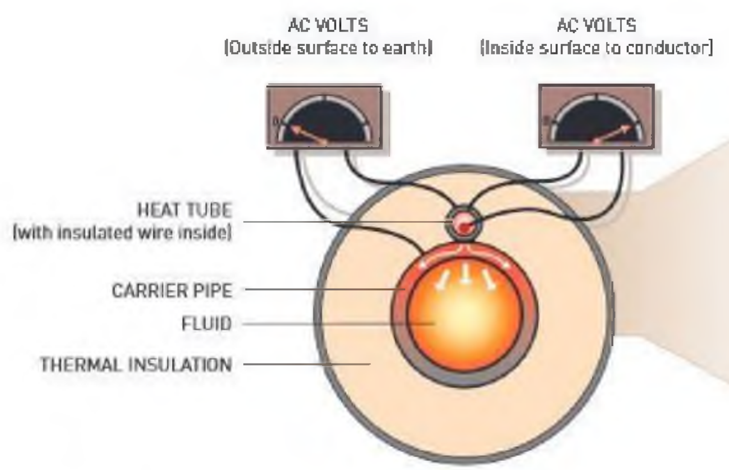


Figure 6.6: Heating element system [6].

This heating method can only efficiently heat up to 15 miles of pipe. If the entire pipeline is traced with a heating element therefore, additional circuits are needed. This makes it difficult for designing the Uinta Express Pipeline because the line may need small power stations in between the pumping stations (depending on the terrain and the distance between stations). The crude is fairly liquidated as it passes through a pump, the most likely position in the pipe the crude has a chance to cool is in the center between two pump stations. So a logical location for a heat source would be in the center of the two pumps. There are multiple locations across the Uinta Express Pipeline route that has access to the electrical grid; but a very reasonable option for powering the heating wire is to run the power in the same ditch as the pipeline. That way the power could supply at any location along the route, including future modifications to the pipeline.

6.5.4 Heat Transfer

The heating system consists of an insulated wire installed inside a magnetic heat tube. The insulated wire is connected to the heat tube at the end termination, and an AC voltage source is connected between the heat tube and insulated wire at the power connection. AC current flows down the wire, returning on the inside surface of the tube. This design allows the heat to safely heat the magnetic tube, which in turn, causes the current flowing in the heat tube to be concentrated on the inner surface. The current concentration is so complete there is virtually no measurable voltage along the outer wall of the heat tube. Heat is also generated due to the resistance of the heat tube and wire, and through currents in the heat tube. Since the heat tube is attached to the process pipe and completely within the thermal insulation system, heat is efficiently transferred into the process pipe [7].

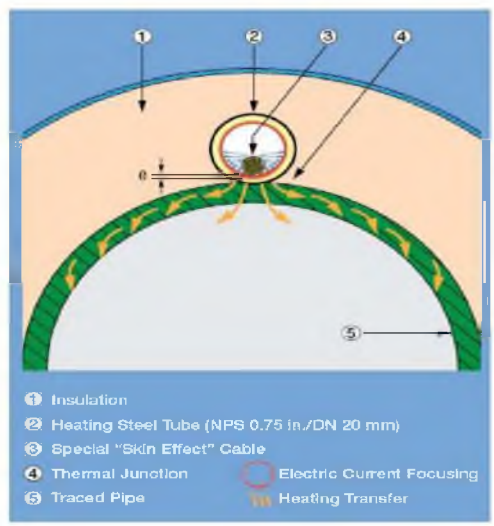


Figure 6.7: Heat Transfer [6].

6.5.5 Power for Heat Element

Table 6.4 below is made available by Pentair, one of the largest companies in developing pipe heating technology. The company specializes on skin-effect heat tracing methods. Table 6.4 describes various products and their specifications the left column of data is the type of wire and heat element sold by Pentair. This table indicates the increased voltage used for longer length of heated pipe; also notice power usage depends on the temperature required.

Table 6.4: Pentair Product Specifications: Heating element capacities [8].

	Maximum circuit length ft (m)		Maximum exposure temperature		Maximum power output* (Watts/ft)	Maximum voltage (Vac)
LBTV2	1125	[343]	185°F	[85°C]	10	277
SLBTV	2000	[610]	185°F	[85°C]	—	277
VLBTV	12,000	[3660]	185°F	[85°C]	20	600
VLKTV	6000	[1829]	420°F	[215°C]	20	600
MI	5000+	[1524+]	1200°F	[650°C]	82	600
SC	12,000	[3659]	482°F	[250°C]	—	600
STS	82,000	[24,993]	392°F	[200°C]	49	2000–5000

* Design dependent

6.6 The Pump Stations

The origin station will consist of truck offloading racks, product storage, pumps, launcher/ receivers, piping, valves, fittings, and power generation. This origination facility would be located on private property and would be approximately 20 acres. The four intermediate stations for the project are approximately five acres each and located on private property. There are seven main line block valves locations and other minor above ground accessories that also will be located on private property [4].

Pump stations are responsible for the delivery of crude oil from the source to the Tesoro Refinery which is about 135 miles long with a 1,208 feet overall elevation change. A pump stations requires a system of pumps, truck offloading racks, product storage tanks, launcher/ receivers, valves, fittings and power generation components. Table 6.5 below shows the unique information for each pump station, miles between stations and elevation changes.

Table 6.5: Pump Station Data: Altitude and pipe length between stations.

Pump Station	Altitude (ft)	Length to Pump 1 (miles)	Length to Pump 1 (ft)
1	5,443	0	0
2	6,823	24	126,720
3	9,677	50	264,000
4	6,302	75	396,000
5	6,781	110	580,800
(Refinery) 6	4,235	131	691,680

The first station is the primary pump station which requires the most pumps and acreage to accommodate for the incoming and outgoing of traffic and requires much more equipment used to load the oil into the pipe.

Table 6.6: Pipeline Sections: Head added by the pump due to elevation and head loss.

Pipe Section	Elevation Change (ft)	Distance Change (miles)	Distance Change (ft)	Head Loss	ha
1-2	1380	24	126720	1443.3	2823.3
2-3	2854	26	137280	1563.6	4417.6
3-4	-3375	25	132000	1503.4	-1871.6
4-5	479	35	184800	2104.8	2583.8
5-6	-2546	21	110880	1262.9	-1283.1

The total head a pump station needs to provide is h_{a}, negative head means oil can flow by gravity. So pump station 3 and pump station 5 were designed to be back up pump stations. As seen in Table 6.6, there are sections of elevation decrease (from pipe station 3 to 4 and from pump station 5 to 6. In these sections, oil flows by gravity and velocity increases. In order to maintain the flow rate between downhill sections, gate valves should be used to allow for flow restrictions and adjustment. In case of significantly large minor losses caused by gate valves, pumps station 3 and pump station 5 need to be set up as back up pumps.

6.6.1 Pump Selection

Throughout the entire pipeline, pumps must provide 1,750 gallons per minute flow rate. Pressure in the pipe will stay constant at 1,200 to 1,400 psi between each pump station. For the primary pump station #1 the pumps should provide 2,823 ft of head, for pump station 2 the total head is 4,418 ft of head, for pump station 4 the total head is 2,584 ft. Due to crude oil's high viscosity and wide range of application conditions, rotary pumps are well suited to handling crude oil. Rotary pumps are used for transport, refining and for high working pressure pipeline sampling applications. While compatible with cast iron, pumps for refinery and pipeline sampling applications are typically steel. Pump construction will depend on the particular oil and application. Many crude oils contain dirt, sand, and other particulate prior to refining. Often pumps for dirty crude oil are supplied with hardened parts to prevent the particulate from damaging the pump.

The recommended pump that meets these qualifications is produced by the German company Leistritz, model L3HG. It can accommodate up to 880 gallons per minute, capable of withholding 2,320 psi, and outputs 1,800 feet of head. By itself it would not be able to handle the requirements but by varying the number of pumps and their unique configuration the pipeline requirements can be met.

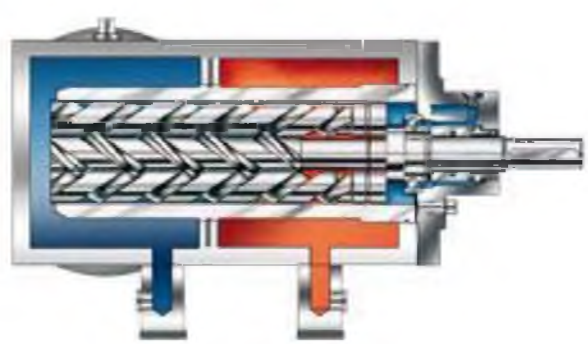


Figure 6.8: Leistritz L3HG Pump: Designed for oil and gas industry.

6.6.2 Pump Configurations

There are three different types of pump configuration, single pump, pumps in series, and pumps in parallel. Single pumps are used where a pump can meet the head, flow rate, pressure demands [4]. Pumps in a series can increase the total head but do not change the flow rate. Pumps in parallel increase the flow rate but do not change the head. In case of pumps failure, at least one pump or one set of several pumps in series should be included in each pump station.

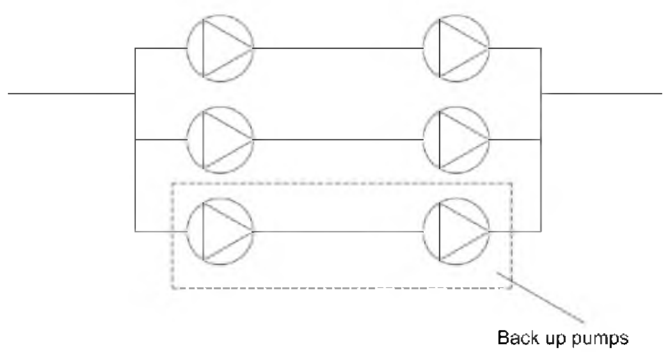


Figure 6.9: Configuration for stations #1 & #4: Four pumps in series and parallel with two backups.

In order to meet the required demands for pump stations #1 and #4, two pumps in series as a set and three sets in parallel are required with backup sets (Figure 6.9). For pump station #2, three pumps are needed to installed in series as a set and three sets in parallel, one of the three sets is backup as drawn in Figure 6.10.

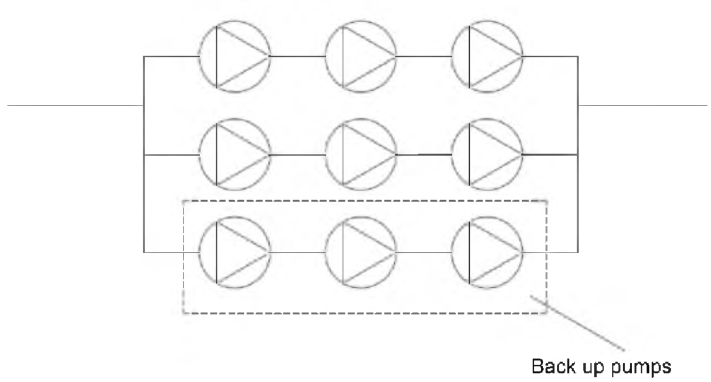


Figure 6.10: Configuration for stations #2: Six pumps in series and parallel with three backups.

For pump station #3 and #5 only two pumps are require in parallel but there are no additional backup pumps because this is a section of pipeline that the elevation head gain by gravity is actually higher than the total head losses therefore these two pump stations are backup stations. It will be known once the system is in operation how much they will be needed (Figure 6.11).

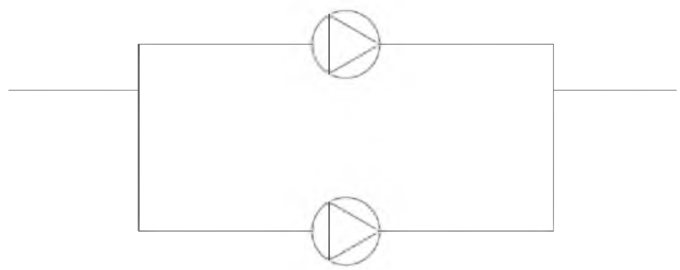


Figure 6.11: Configuration for stations #3 and #5:
Two pumps in parallel without backup.

6.7 Conclusion: Energy Requirements

These pump stations, the pumps inside and the heated pipeline will demand a significant amount of electricity. There are only two pump stations (#3 and #5) that are located 2 to 7 miles from the electric grid. Electricity is easily accessible to the other 3 pump stations. There are also power requirement in between the pipeline to operate the heating pipe wire. Therefore, there are two possibilities in order to supply power to the pipeline and its components. First being the most economical is to connect the pump stations to the nearest grid access point requiring a tributary branch from each pump station. The second option is to connect the pipeline to Tesoro's refinery and run the electrical wire along the same trenched path as the pipeline throughout the entire 135 miles which undoubtedly would require more material but would allow for less permitting and tributary trenching from the main path. At this point in time further analysis is required by electrical engineers to explore the best course of action.

The electricity requirements identified in this report are the pump stations and the pipeline heat wire. The power required from the pumps was calculated in section 6.4.1 and is 1.994 Mega Watts. The pipe heating wire requires 20 watts per foot which totals 14.256 Mega

Watts. Therefore the total required power to pump the crude 135 miles is approximately 16.25 Mega Watts. This number is then converted into electricity by unit conversions. Assuming Tesoro buys power at 4 to 5 cents per kilowatt-hour and the system is operating 24 hours per day the total electricity cost of using this pipeline is approximately $17,021 to $21,276 each day.

6. 8 References

[1] Amy Joi O'Donoghue & Whitney Evans, Tanker spills, pipelines raise questions about crude oil transport, Salt Lake City, Deseret News, 2014.

[2] Guillaume Vinay & Anthony Wachs, Start Up of Gelled Waxy Crude Oil, Jakarta, Society of Petroleum Engineers, 2009.

[3] David C. Whittekiend, Uinta-Wasatch-Cache National Forest; Utah; Uinta Express Pipeline Project, Salt Lake City, Authenticated U.S. Government Information, 2014.

[4] Robert L. Mott, Applied Fluid Mechanics Sixth Edition, Upper Saddle River, Pearson Education, 2006.

[5] George E. Totten, Technology, Properties, Performance, and Testing, Fuels and Lubricants Handbook, 2003.

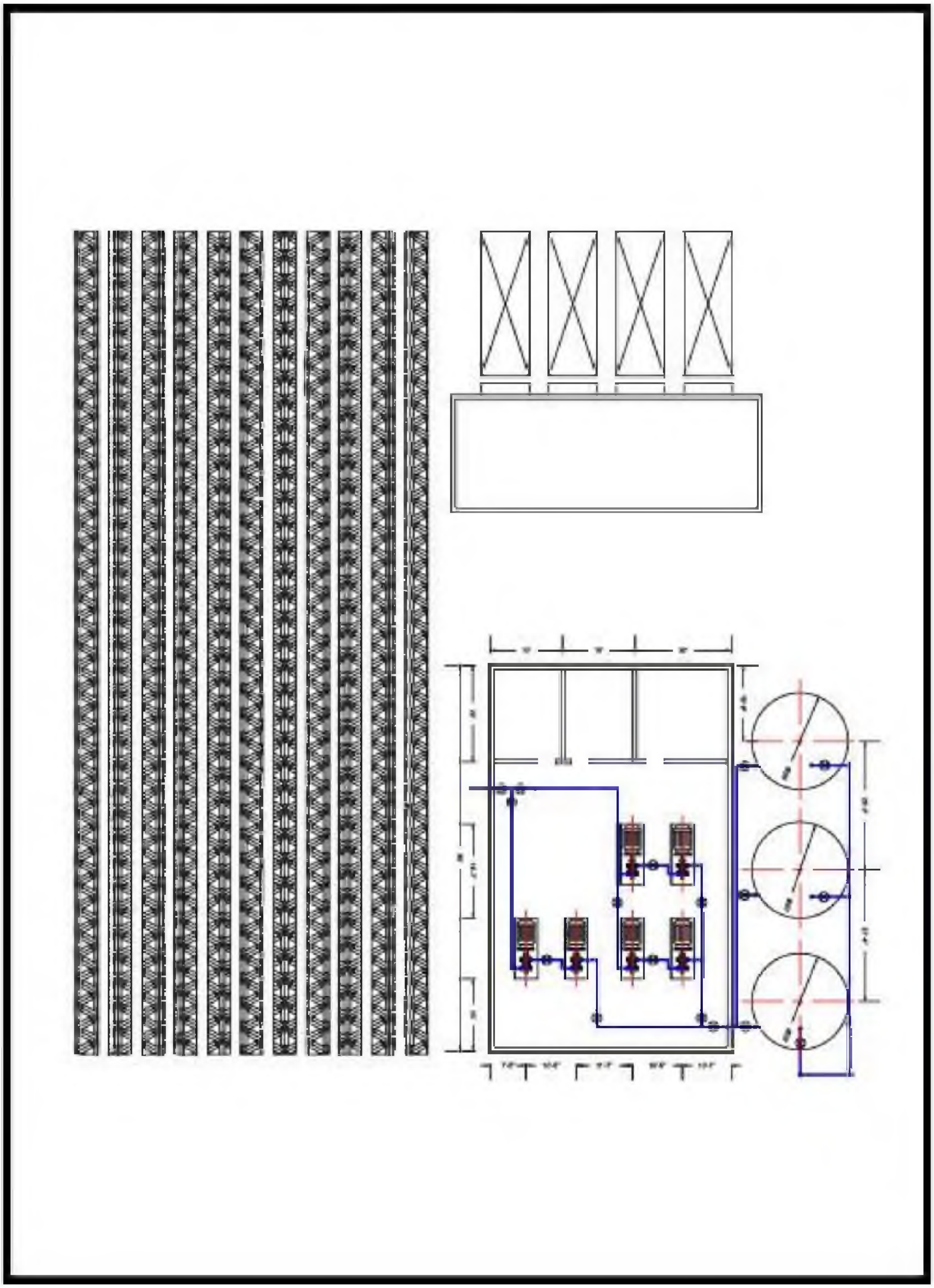
[6] N. Fenster, D.L. Rosen, S. Sengupta, J. McCormick, Electric heat tracing design for impedance and skin effect systems, Vancouver, IEEE Industry Applications Magazine, 1996.

[7] Sean McCandless, Crude Oil Pumps, Birmingham, Upstream Pumping Solutions, 2013.

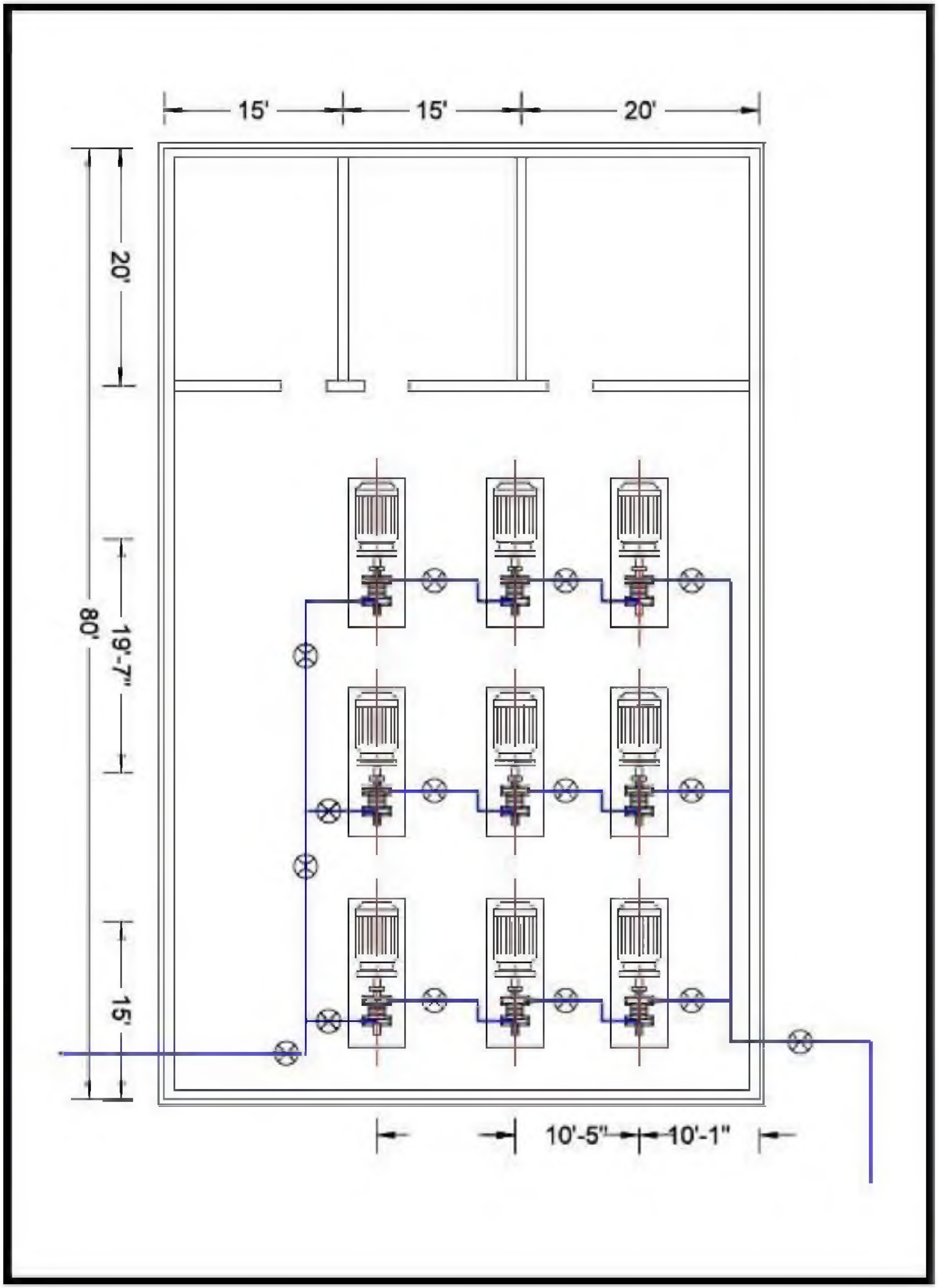
[8] Leistritz, Screw Pumps, Hamburg, Leistritz Pumps LTD, 2014.

[9] Pentair, Thermal Building & Industrial Heat Tracing Solutions, Houston, Pentair Publications, 2014.

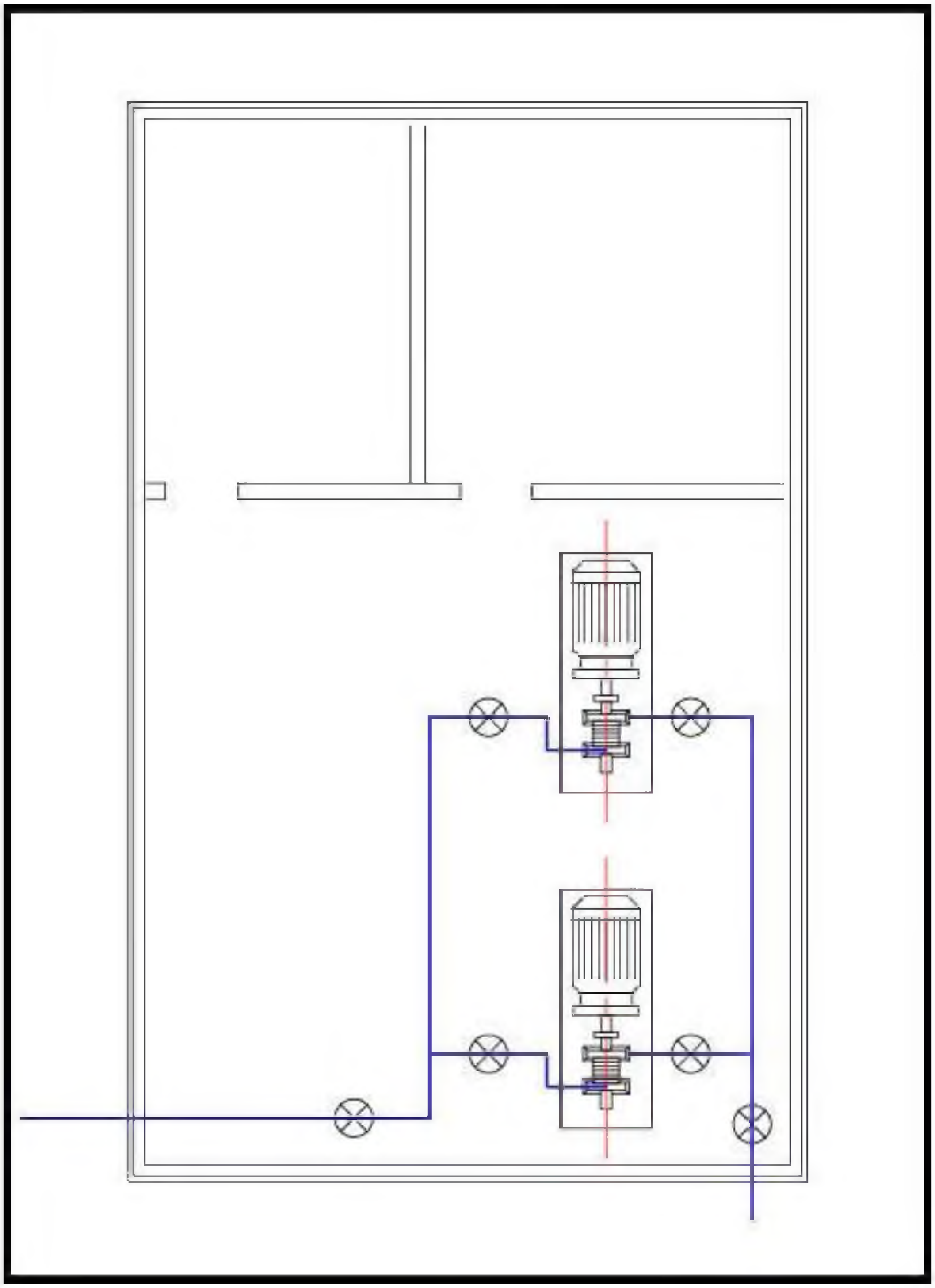
Appendix I: Pump Station #1 Design



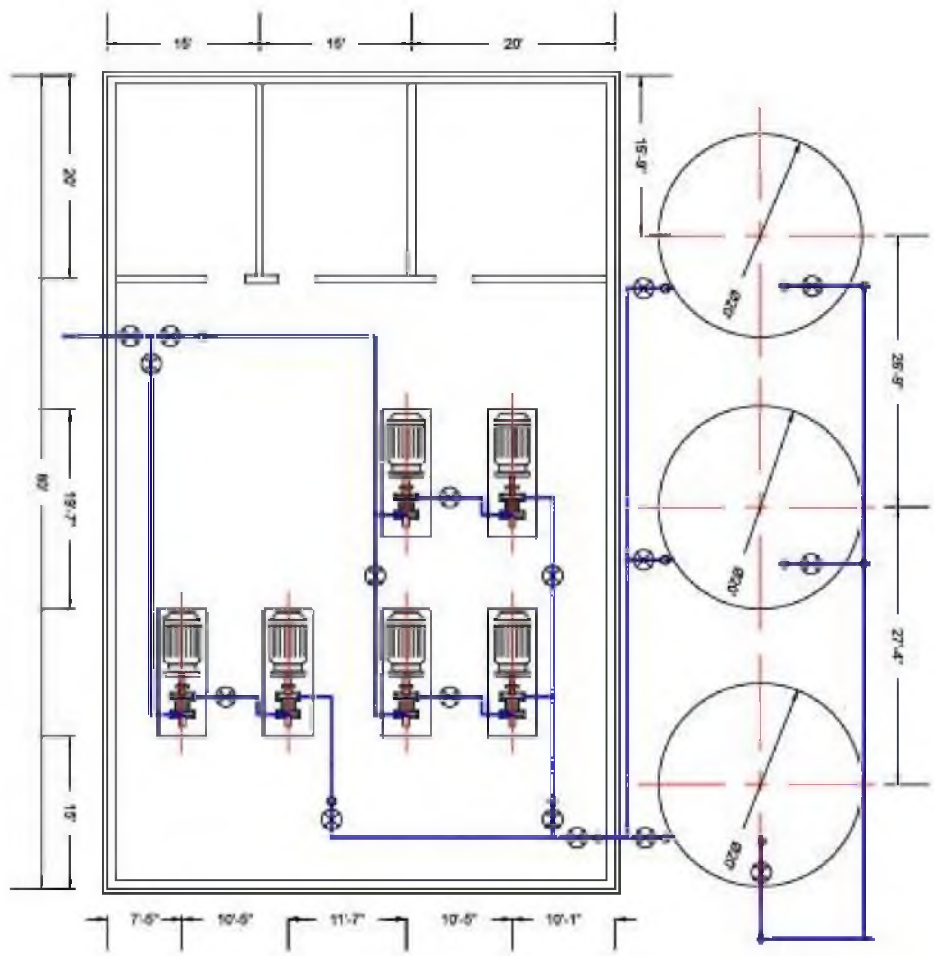
Appendix II: Pump Station #2 Design.



Appendix III: Pump Station #3 & #5 Design.



Appendix IV: Pump Station #4 Design.



Chapter 7

Pipeline Maintenance

Abstract
The Uinta Express Pipeline Project proposes to transport waxy crude oil from the Uinta basin to refineries near Salt Lake City. This waxy crude has a high paraffin content and must be kept above a minimum of 95° F. This article presents a number of difficulties associated with the maintenance of the project and solutions to combat the problems that might arise.

Heating elements, which are the primary system in place for the prevention of fouling will be utilized in the UEP. Surface analyses of the viable types of heating elements will be conducted and include tracer, coil, and jacket heating elements. Information about the selection process of heating element type is included. Additionally, methods for placement and level heat output are reviewed.

Secondly, the article discusses the use of scrapers, commonly called pigs. The scrapers serve a variety of functions dependent on the phases of the pipe construction. The scrapers used is also dependent on their purpose which may range from traditional scraping, to corrosion spraying, or ultrasonic equipped. Other scrapers reviewed include gelled scrapers, foam scrapers, and scrapers with varying attachments. Their diverse contributions to the longevity of the pipe are analyzed and an implementation pattern is suggested.

Corrosion and its causes are discussed in addition to preventative measures such as protective coatings, cathodic protection, selection of proper durable material, and corrosion inhibitors. Environmental conditions and testing methods are also studied to best prevent any lapses in safety as a result of weakened pipes.

7.1 Introduction

The maintenance of such a large economic endeavor is integral to lengthen the lifespan of the project. If any one component were to fail and no maintenance plan in place, due to the nature of the fluid, it might take hundreds of thousands of dollars to repair all further damaged components and get the pipeline restarted. Utilizing routine maintenance and scheduled services can extend the life span of the operations. With a maintenance system in place, the damaged component could be quickly discovered and readily repaired or replaced. The UEP will transport waxy crude so heating elements, scrapers, and corrosion control must be incorporated in the maintenance plan. Performing preventive maintenance with the three processes, potential hazards to the environment and the pipeline are reduced [1]. The use of scrapers, corrosion mitigation, and heating elements are intertwined and dependent upon each other to reach optimal performance.

7.2 Heating Elements

The waxy crude being transported in this particular pipeline is of very low grade and has a high paraffin content [2]. This means the crude is semi-solid and non-Newtonian at ambient temperature. As such, the waxy crude has a high pour point that must be maintained throughout its journey down the pipeline [3]. The Uinta black wax crude must remain above 95° F and yellow wax above 115° F to prevent congealing [4]. At temperatures below the pour point, also known as the cloud point, the waxy crude begins to form crystals which join together to induce gelling. This point is known as the wax appearing temperature (WAT).

The zeroth law of thermodynamics states that if two systems are in thermal equilibrium with a common third system, they must both be in thermal equilibrium with each other. Additionally, the second law of thermodynamics states that two systems of differing thermal properties independent of each other, will eventually reach a thermal equilibrium when allowed to interact. These laws are important when considering the thermal dissipation down the proposed 135-mile pipeline [5]. With respect to the zeroth law, the two systems in question are the soil, which can be seen as a temperature reservoir and is therefore unchanging, and the heated waxy crude in the pipeline, which is the system whose temperature will drop and have significant consequences. The third system with which they must both achieve equilibrium is the insulated pipeline. Initially these three are not in thermal equilibrium, but, given the second law, it is a certainty that over time, they will indeed reach a common temperature if no outside energy is added to the system. Because the soil mass is large enough to be considered an energy reservoir [6], or in other words, an energy sink, its' temperature as a whole will not change whereas the pipe and heated oil will decrease in temperature to reach equilibrium with the soil. This soil temperature is usually below ambient temperature which is well below the cloud point of the waxy crude.

Wax formation will begin once the oil begins nearing equilibrium with the soil. Initial formation of wax tends to occur along the interior surface of the pipe, or the area of least energy. The pipe surface is the third system in the zeroth thermodynamic law and equilibrates more readily with the soil because the vast quantity of soil absorbs and dissipates the energy away from the waxy crude. Thus, the waxy crude nearest to the pipe surface will decrease in thermal energy until it reaches its WAT and begins to congeal. Additionally, the surface of the pipeline is a location of low kinetic energy [6] due to the higher turbulence and lower heat. Unlike the center of the pipe where kinetic energy is transferred to other waxy crude particles, the energy of the waxy crude near the sides is transferred to the pipe and then to the soil. This process continues slowly until further down the pipe, these particles lose too much energy and adhere to the walls of the pipe. In order to initially prevent it, a warm up fluid is passed through the pipe until the soil around it rises to the desired temperature [6]. Once this point is reached waxy crude may be pumped through. This warm up process will retard the heat loss rate.

The eventuality of congealment in a very long pipeline implies the need for heating elements which introduce additional thermal energy and prevent fouling. Very specific calculations must be made which take into consideration many aspects of the pipeline including initial and final temperature of the oil, the soil, the heat transfer coefficient of the oil, soil, and pipe, dimensions of the pipe, and properties of the flow of oil [6]. These calculations must be made for a variety of soil conditions, atmospheric conditions, both laminar and turbulent flow, pipe depths, and pipe types. After these calculations are completed, the pipeline data must be evaluated and points of high congealment potential must be identified. The data collection must be repeated after the first heating element is proposed and for every subsequent proposal to ensure the most accurate and effective system. However, if two heating elements are near enough to be joined the resulting fouling is acceptable, one heating element may be eliminated and the other placed at a location between the initial placements. Mild fouling is acceptable between the heating elements considering there will be scrapers periodically passing by and removing blockage. Developing a balance between economy and effectiveness is ideal considering the lifetime of the pipeline and the operating costs of excess heating elements. The waxy crude is best kept hot but not to the point of boiling due to the associated problems including increased turbulence, pump cavitation, and pipe stress. These heating elements will serve to maintain the waxy crude above its cloud point yet below boiling.

7.2.1 Types of Heating Elements [3]

Initially, the waxy crude is heated in a crude oil heater which can take many forms depending on the source material. In line heating elements are the most vital for the prevention of fouling. The following describe the most common.

7.2.1a Heating oil by steam in tanks through coils [3]

Heating the oil using steam in tanks fed through a series coils is one of the more efficient ways of heating the pipeline. At prescribed intervals, these stations are placed on the pipeline. Steam produced in an exterior tank is pushed through the small pipes attached to the surface of the pipe. The steam releases its energy to the pipeline and returns to liquid form. The water is then deposited to the condenser tank and reused. The release of energy to the pipe heats the oil.

7.2.1b Steam Tracer Line

Similar to a steam coil, a steam tracer line is a small diameter pipe but it is instead run alongside the length of the oil pipe. The small line is made of tough and durable material to withstand constant heating and the pressure associated with the superheated steam. A conductive compound is applied between the main and smaller pipes to ensure efficient heat transfer. Both the tracer line and oil pipe are insulated to reduce energy loss. The number of tracer lines depends on the size of the pipe and the amount of heat needed.

7.2.1c Hot Water Jacket

A jacketed pipe consists of the oil pipe operating at normal conditions but it has a secondary, exterior pipe. Between the oil pipe and the exterior pipe, there runs a heating medium, usually hot water. This jacket tends to run the length of the pipe. The advantages to this process include even heating distribution which can prevent burning or extra stress on any isolated area.

7.2.1d Electrical Heating of Pipeline

Electrical heating is similar to steam heating in method but different in medium. Instead of pipes, this process uses wires welded to the pipe surface [7] and instead of steam, it uses electricity. It transfers energy to the oil pipe to prevent fouling.

7.2.2 Heat Requirement

Heat requirement per unit length must be determined before applying any of the heating elements. For example, the heated oil line in Sumatra maintains a temperature of 145° F for proper flow [7]. The equation for the determination of the heat requirement per unit length is:

퀸 = ∑ 퓩 = 휧[휅휇 + □휅 휅 팺 + 휅□ 퀸 □ 퓩□] [3]

Where:

d= Inside diameter of pipe
□= film thickness for oil
g = Specific Gravity of Oil
L_o = Latent heat of oil
$□_T$ = Thickness of pipe
g_T = Specific gravity of metal

C_T = Specific heat of metal
T_W = Temperature at the wall of pipe
T_o = Temperature of outside media (soil)
t =time of heating
□= Heat transfer co-efficient (soil to air)

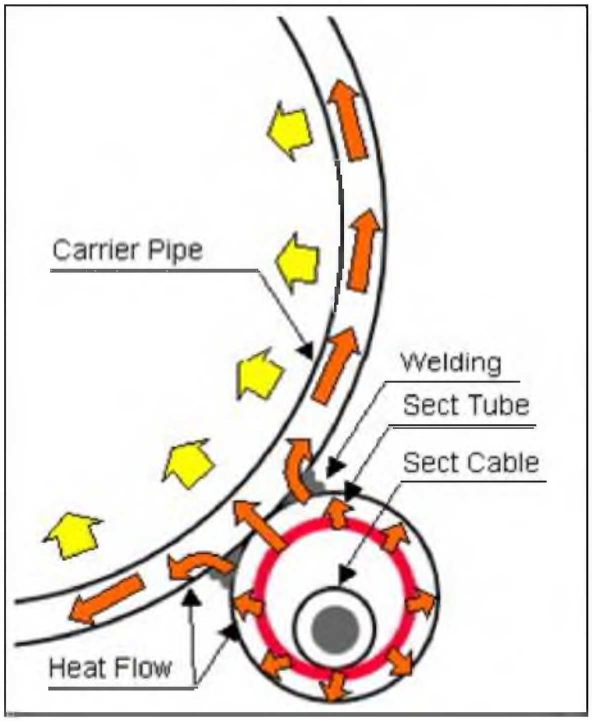


Figure 1: SECT Tracing System: Heat motion Diagram: Heat from the SECT cable travels to the carrier pipe to the fluid. The SECT cable is enclosed in a tube welded to the surface of the carrier pipe [8].

The company responsible for the UEP is exploring the use of heat tracers on the outside of the pipes' .375-inch wall (SL tribb)[4] allowing for a continuous and inexpensive source of sufficient heat similar to the SECT system of the Sumatra pipeline. The heat flow process of the SECT system, or skin effect trace heating system, which functions very similarly to the desired heat tracers for the UEP is depicted in Figure 1.

7.2.3 Congealing

If the pipeline is ever required to stop, it is important to know that fouling will occur [3]. To prevent fouling, a few measures are available. For shorter pipelines or extreme situations, oil may be displaced with water while still hot. This, however, means the disposal of all oil in the pipeline as it becomes emulsified with the water and is no longer usable. If additional pumps are present along the pipeline, tanks may be installed at intermediate points and oil pumped into them. In the event of halted pipe flow, the company for the UEP plans to install four 25,000 barrel capacity heated tanks along the line to preserve the integrity of the pipeline [4].

7.2.4 Degelling

There are a number of ways to remove buildup in the pipe. The method of buildup removal depends of the severity of the buildup and pipe characteristics.

7.2.4a High Pressure

Before thorough cooling of the pipe, high pressures should be applied to remove as much oil as possible. The pipe design should be such that it can withstand these high pressures.

7.2.4b Solvent

Any higher refined solvent such as gasoline or kerosene should be pumped through the pipe. The properties of light oils are such that they dissolve waxy crude. These solvents in these quantities however would be very expensive.

7.2.5 Insulation [3]

The problem with pumping waxy crude is the heat losses to the earth. In order to prevent these heat losses, the pipe must be insulated. This insulation also acts as corrosion control against the sulfates and other corrosive chemicals in the soil. When choosing an insulating material, the cost must be reasonable for the material life and the application. Also, the moisture penetration must be low if electrical components will be used and the material must have sufficient mechanical and thermal shock resistance. When adhering the insulation to the pipe surface, the bond must be such that it will not degrade before the end of the pipe life.

Tests should be conducted for new-to-market materials and caution should be taken to ensure coating preservation. The UEP is interested in using a HDPE coating, which is a common material and that will require little prior testing[9]. However common the material is, manufacturer specifications should always be referenced.

7.2.6 Excessive Gelling

Natural fouling will occur so scraping devices are run through the pipeline to remove any gelled material. All precautions must be taken to prevent excessive fouling in the pipeline. If proper maintenance is performed this small problem will remain small. If, however, proper procedures are disregarded, the easily preventable situation of excessive gelling could quickly result in a completely clogged pipeline, refered to Figure 7.4 [10]. At this point, the pipeline will need to be excavated and cleaned or completely replaced.

7.3 Scrapers

There are various types of scrapers used in the pipeline industry and each scraper has a specific purpose or designed usage. The type of scrapers that the UEP will require is dependent on the section of the pipeline to be maintained. Determining the intended use of scrapers will be the first concern, followed by the order in which the scrapers will be used This is the suggested order the UEP should utilize scrapers and particular usages [10] [1].

7.3.1 Foam Scrapers

Chemical gelled or foam scrapers are mainly used to rid the conduit of obstructions like debris. Foam scrapers, as seen in Figure 7.1 [11], purge the pipeline of obstructions and items left behind from the construction prior to the hydro-testing which checks for leaks. This should be the first scraper used by the UEP, clearing the pipeline for first use.

Figure 7.2: Foam Scraper: Foam scraper to clear debris [12].

7.3.2 Ultrasonic Scrapers [13]

The next type of scraper available at the industry's disposal is equipped with ultrasonic technology. The ultrasonic scraper gauges the thickness of the steel pipe as the device is propelled through the line. The scraper obtains readings to assist in computer modeling to effectively monitor and indicate where the pipe wall is waning. The ultrasonic scraper is capable of identifying cracks, fractures, and corrosion while passing through the pipeline. The ultrasonic device also analyses welds, which are a very important facet of pipeline operations because the welds have to withstand the pressure exerted by the material transported by the pipeline[9]. With the device, the UEP can effectively assess the strength of the welds before the hydro-test, eliminating damaging ruptures and potential pipe replacement.

7.3.2a Ultrasonic scraper's pros and cons [13]

With every product or apparatus there will be positive and negatives. The ultrasonic scraper is no different and has the pros and cons listed in Figure7.3.

[9] Welds was a huge issue in 1975, during the construction of the Trans-Alaska Pipeline nearly 4000 welds were found to be faulty. "800 Miles to Valdez: Building of the Alaska Pipeline" by Roscow, James P. p. 151

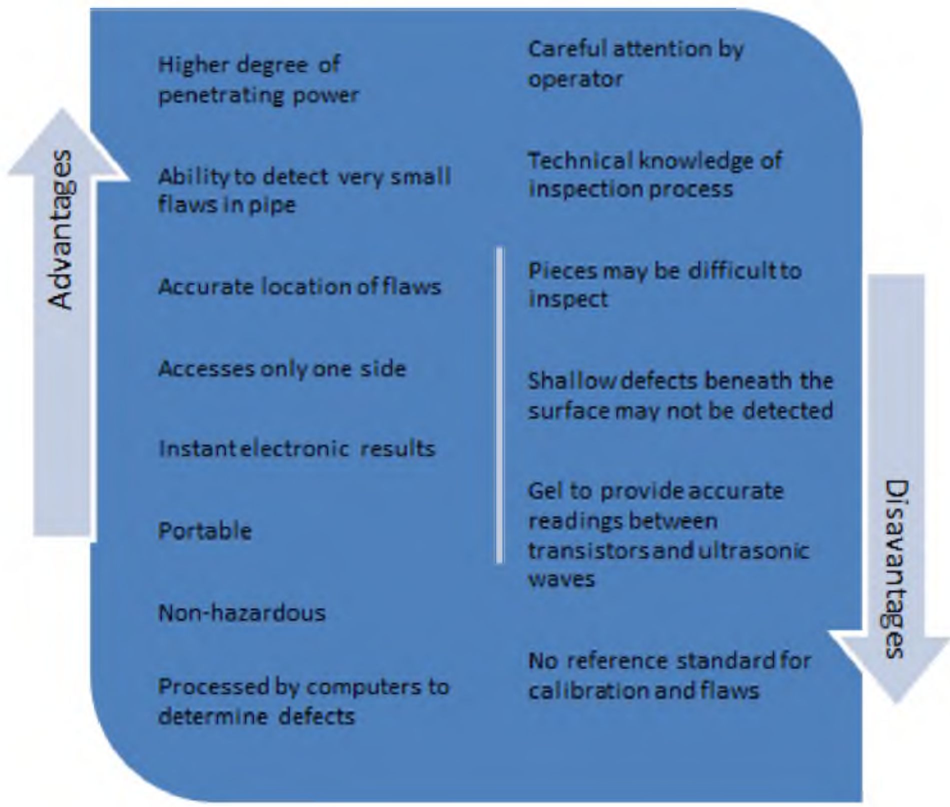


Figure7.3: Pros/ Cons: Advantages and Disadvantages of Ultrasonic Scraper.

7.3.3 Traditional Scrapers [1]

The next kind of scraper the UEP would use once the pipeline is in operation is the traditional style. This apparatus is used to clean the inside walls of the pipe when traveling down the conduit. The traditional scraper rids the conduit of excessive buildup that can be corrosive to the material of the pipe and restrictive to fluid flow. A shunting scraper is a traditional scraper that is often used and it is heavy multiple module design used to remove excessive build up from the walls of the cylinders. The shunting scraper is also designed so that the first module can operate while being damaged. Moreover, these devices reduce the amount of pressure the pipe could potentially experience and increase the flow of material transported by the conduit. The scrapers purpose is to rid the passageway of excessive buildup such as that seen in Figure 7.4. Regularly using the scraper will increase the life cycle of the pipeline. The pump stations would be less strained when the conduit is able to reach its maximum flow rate.

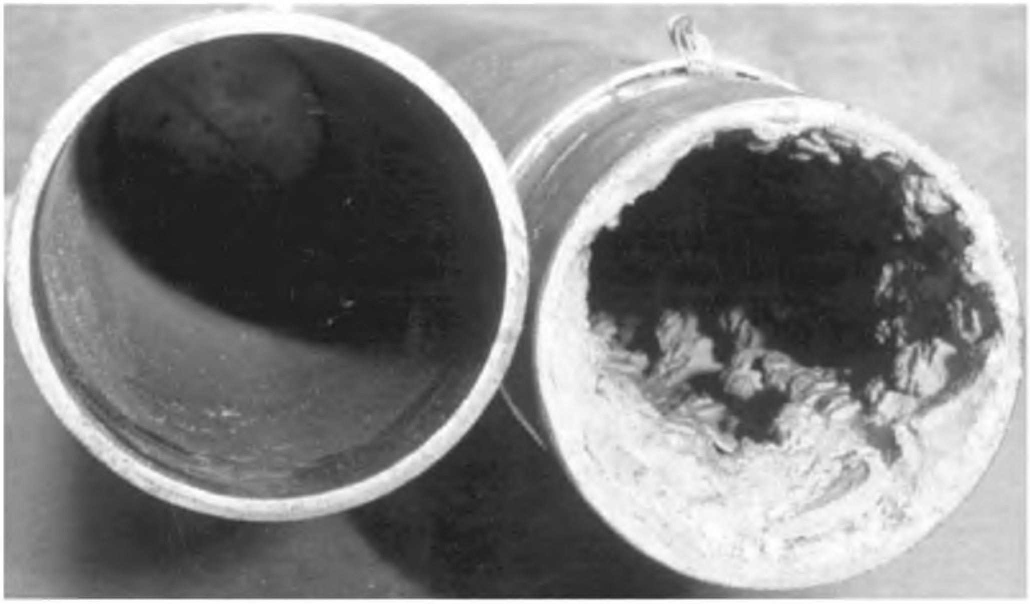


Figure 7.4: Pipeline build up: Excessive residue in a pipeline segment: This image illustrates excessive of wax, oxidation, and scale accumulating inside the pipeline [14].

7.3.4 Corrosion Inhibitor Scrapers [1]

For corrosion concerns, there is a scraper designed to spray a corrosion inhibitor when run through the conduit. The scraper is used to coat the interior of the pipeline whilst passing within the ducts. This coat is designed to prolong the life of the cylinder segments and delay replacement. Figure 7.5 shows how the corrosion inhibitor scraper will apply a residue to reduce corrosion. This should be the next scraper the UEP uses to add a layer of protection against corrosive materials and deposits left by product transportation.

Figure 7.5: Corrosion inhibitor scraper: CIS spraying the interior of pipeline [15].

7.3.5 Gelled Scraper [4]

A gelled scrapper is a chemical compound that can be employed in various locations along the conduit. The aim of this scraper is to clean the cylinders between the use of different products. The gel reduces the amount of cross contamination or comingling that can occur when different products are being shipped from one point to another using the same conduit. Unlike the other scrapers that can only be placed in service at certain points, the gelled scraper can be inserted via valves anywhere along the pipeline. The gelled scrapers are a better option than the separation orbs because the orbs yields a higher amount of product mixing together. The UEP would use this gel to separate the black from the yellow waxy crude if the refinement required the UEP to do so. In Figure 7.6: Gelled Scraper: Wax removal, the gel can be seen right before it dissolves small buildups and wax deposits.

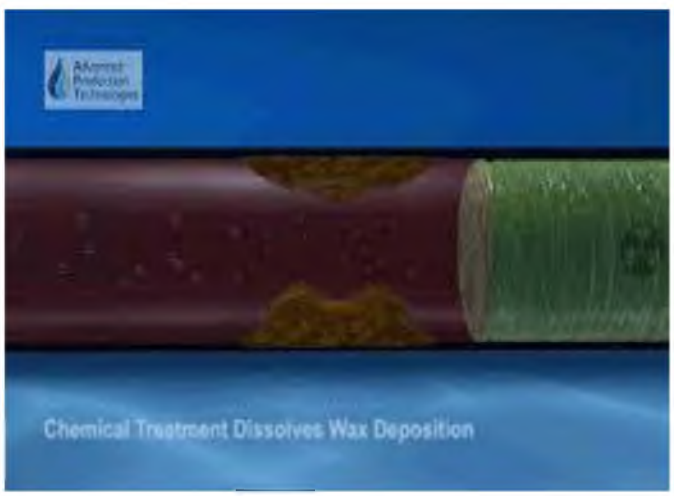


Figure 7.6: Gelled Scraper: Wax removal [16].

7.3.6 Choosing the Proper Scraper [4]

When choosing the proper scraper to be used, the configuration of the pipeline setup has to be factored in. The location of Tee's, Wye's, elbows, reducers, bend radius, and diameter of the pipe will determine the style and type of scraper that would best serve the purpose. The use of multiple scrapers will often be the solution for different sections of the pipeline. Each segment may have obstacles unique to that region of the pipe. Two other determining factors are at what speed the scraper will be traveling and the length of the pipeline. The speed is vital because the polyurethane seal on the scrape could be damaged as a result melting due to excess frictional heat. The distance traveled could have a similar frictional effect or thermal expansion could occur causing the scraper to become stuck within the pipeline. The three main areas of the UEP that would require different scrapers would be pump stations, terminals, and the pipeline itself. The pipeline would use the traditional scrapers. The terminal, where the vast majority of the Tee's, Wye's, Elbow, gate valves, etc are located, would require various styles of scrapers and attachments. At the pump station, gelled scrapers would serve best to prevent cavitation from occurring at the pump and losing the prime.

7.3.7 Scraper Attachments [1]

Upon choosing the proper scraper to be used, the appropriate attachments must be decided. There are various types of fixtures that can be added to the scrapers. Brushes are used to clean the interior of the pipe from oxidation, scale build up, and hardened debris. Brushes have little to no effect on wax build up for the bristle will quickly be matted. Discs are employed where blockage may require the device to be reversed such as in Figure 7.7 Disc Attachment: Disc. Disc scrapers like gelled or foam scrapers are preferred during construction phases. Cups are more accepting during diameter changes and are used to dislodge a scraper affixed with discs. The cup scrapers such as those in Figure 7.8:Cup Attachment: Cup are heavier than the scrapers with the discs. The scrapers can be a combination of attachments and modules depending the needs of the pipeline.

Figure 7.7: Disc Attachment: Disc [17].

7.3.8 Why Scrapers Become Stuck

Figure 7.8: Cup Attachment: Cup [17].

There are several reasons that scrapers might get stuck within the pipeline. The most common cause is operator error. Not choosing the proper scraper for the task or not accounting for the variables of the pipeline configuration are common mistakes. Another is using the wrong style of scraper in the terminal area and wedging the device in a bend of the pipe. Another possible scenario is if there is excessive buildup of deposits in the conduit from a lack of maintenance or due to a faulty heating element. Other potential blockage sites are gate valves that are not completely open or Tee's missing the mesh screen allowing the scraper to slide by [5]. The UEP has to devise a specific set of scrapers for each section of the pipe to avoid obstruction of the conduits and failure of the pipeline.

7.4 Corrosion

Corrosion is defined as the gradual destruction of a material, usually a metal, by chemical and environmental reactions. Unprotected pipelines, whether buried in the ground, exposed to the elements, or submerged in water, are susceptible to corrosion. Without proper maintenance, every pipeline system will eventually deteriorate. Corrosion can weaken the structural integrity of a pipeline and make it an unsafe vehicle for transporting potentially hazardous materials. However, technology exists to extend pipeline structural life indefinitely if applied correctly and maintained consistently.

7.4.1 Corrosion Overview

In response to recent oil spills and pipeline disasters in the past decade, panels of experts within the industry have attempted to reconcile with the public and explain the nature of pipeline disasters. In one of many attempts, Oliver Moghissi with DNV GL offered an explanation of corrosion and its effect on crude pipelines: "Corrosion is one of many possible threats to a crude oil transmission pipeline that must be managed. It should be noted that crude oil by itself is not corrosive at pipeline conditions, but water can drop out of the crude oil and allow corrosion to occur where it accumulates."

It is the trace amounts of water and sediment that must be accounted for if internal corrosion is going to be prevented or mitigated. Currently, there exist many conventional methods of controlling pipeline corrosion, all of which are employed on modern pipelines and it is expected the same methods would be used for the UEP. The problem is that the pipelines are so long (in the case of UEP, spanning nearly a third of the length of the state of Utah) that there will inevitably be some failure despite the best precautions and tracking methods. Furthermore, the amount of corrosion produced by the trace water and sediments in the pipeline begins at such a minute level that it is nearly impossible to trace. The progression of the internal corrosion is very slow, making it difficult to identify given that there are no sudden changes to the pipeline that could raise any red flags.

There are many different factors that contribute to internal corrosion:

- Flow rate—considered to be the primary factor of internal corrosion.
- Wettability—the degree to which the commodity can become wet. As mentioned earlier, the source of the corrosion is not the waxy crude itself but the water that can separate from it.
- Emulsion-forming tendency—the event in which two normally immiscible liquids form a mixture, such as oil and water.
- Corrosiveness in brine—a physical property of crude classified by the ASTM.

7.4.2 Methods of Controlling Pipeline Corrosion

7.4.2a Protective Coatings and Linings

Coatings and linings are principal tools for defending against corrosion. Every project is unique, and special consideration must be given to various factors prior to selecting an appropriate protective coating and lining. Soft rubber lining systems are excellent for chemical and abrasion resistance when the commodity has high solids content. Hard rubber lining systems are exceptional in providing chemical resistance when used with mineral acids, bases, organic solvents and aqueous phases. Polymer coatings offer great protection against most solvents, organic and inorganic acids as well as alkaline media, together with extraordinary high resistance to temperature. Polyurethane coatings guarantee rapid curing and excellent bonding to the pipeline even under the most unfavorable conditions, such as high humidity and low temperatures. Polyurea coatings are particularly distinguished by excellent resistance to abrasion and wear, as well as broad chemical resistance. They also feature short curing times making them ideal for projects with small installation downtimes.

Given the commodity of the Uinta Express Pipeline, it is recommended that the pipeline be covered with a polymer coating as the waxy crude will need to be heated during transportation and the polymer coating is the most resistant to high temperatures.

7.4.2b Cathodic Protection

Cathodic protection is a technology that uses direct electrical current to counteract the normal external corrosion of a metal pipeline. It is used where all or part of a pipeline is buried underground or submerged in water. On new pipelines, cathodic protection can help prevent corrosion from starting; on existing pipelines, it can help stop existing corrosion from getting worse. It is sometimes more economically viable to protect a pipeline using galvanic anodes. This is often the case on smaller diameter pipelines of limited length. For structures such as long pipelines, in the cast of the Uinta Express Pipeline, where passive galvanic cathodic protection is not adequate, an external DC electrical power source is used to provide sufficient current.

7.4.2c Materials Selection

Materials selection refers to the selection and use of corrosion-resistant materials such as stainless steels, plastics, and special alloys to enhance the life span of a structure such as a pipeline. Materials selection personnel must consider the desired life span of the structure as well as the environment in which the structure will exist.

The Uinta Express Pipeline will be constructed out of carbon steel pipe. Manufactured carbon steel pipe is the most common material used in commercial mechanical systems. The material features high strength, good ductility, low cost and adaptability for most joining methods. All of these factors make carbon steel pipe ideal for transporting liquid, gas and vapor. The waxy crude that is to be transported in the UEP is no exception.

7.4.2d Corrosion Inhibitors

Corrosion inhibitors are substances that, when added to a particular environment, decrease the rate of attack of that environment on a material such as metal or steel reinforced concrete. They can extend the life of pipelines, prevent system shutdowns and failures, and avoid product contamination. Inhibitors fall into three general categories based on mechanism and composition.

Barrier layer formation inhibitors form a layer on the corroding metal surface, modifying the surface to reduce the apparent corrosion rate. They represent the largest class of inhibitive substances. Neutralizing inhibitors reduce the hydrogen ion in the environment. Typical neutralizing inhibitors are amines, ammonia (NH3), and morpholine. These inhibitors are particularly effective in boiler water treatment and weak acid solutions but have not been widely used on pipelines. Scavenging inhibitors remove corrosive ions from solutions. Well-known scavenging inhibitors include hydrazine and sodium sulfite. These two inhibitors remove dissolved oxygen from treated boiler water. The Uintah Express Pipeline will benefit most from a barrier inhibitor, which will improve reliability and accessibility of the piping and other equipment.

7.4.3 Methods of Tracking Corrosion

One of the biggest problems in preventing and mitigating pipeline corrosion is successfully identifying when it where it is happening—particularly before significant damage has taken place. In the industry, there currently exist several different tools and technologies for monitoring pipeline corrosion.

7.4.3a Magnetic Flux Leakage

Magnetic flux leakage is a magnetic method of nondestructive testing that is used to detect corrosion and pitting in steel structures, most commonly pipelines and storage tanks. The basic principle is that a powerful magnet is used to magnetize the steel. At areas where there is corrosion or missing metal, the magnetic field "leaks" from the steel. In an MFL tool, a magnetic detector is placed between the poles of the magnet to detect the leakage field. Analysts interpret the chart recording of the leakage field to identify damaged areas and hopefully to estimate the depth of metal loss. A MFL operates similar to a pig as discussed in previous sections. The difference, however, is that MFI tools are ‘smart’ in that they contain electronics and collect data in real-time while traveling through the pipeline.

7.4.3b Long Range Ultrasonic Testing (LRUT)

Long range ultrasonic testing is a rapid way of screening for corrosion in pipelines. By fitting a ring of transducers around the pipeline, a wave maker device directs low frequency ultrasonic waves via the transducers, longitudinally into the pipeline wall. The method effectively detects changes in the pipeline’s cross-section, enabling it to identify corrosion and other abnormalities.

7.5 Summary and Conclusion

The Uinta Express Pipeline is a massive project with many facets. This brief report only offers a cursory overview of the maintenance aspects related directly to the pipeline. Proper maintenance and upkeep of the pipeline is critical to a successful future and positive environmental influence. Constantly monitoring the heating elements, scrapers, and corrosion mitigation systems can ensure the pipeline stays active and profitable.

7.6 References

[1] J. Tiratsoo, "Pipeline Pigging and Integrity Technology (3rd Edition)," ed: Clarion Technical Publishers.

[2] M. Clemens. (2014, 12/06/2014). Uinta Express Pipeline -- More Air Pollution & Global Warming. Utah Sierran, 1. Available: https://utah.sierraclub.org/uinta-express-pipeline-more-air-pollution-global-warming.

[3] T. K. Goswami, "DESIGN FEATURES OF HOT OIL PIPELINE SYSTEM," Petrol & Hydrocarbons (Suppl to Chem Age India), vol. 3, pp. 142-148, 1969.

[4] B. Maffly. (2014, 12/05/2014). New pipeline would get Uinta's waxy crude to Salt Lake City. Salt Lake Tribune. Available: http://www.sltrib.com/sltrib/news/57490216-78/oil-pipeline-uinta-crude.html.cs.

[5] U. E. Pipeline. (2013, 12/06/2014). Uinta Express Pipeline. Available: http://uintaexpresspipeline.com/.

[6] G. Chen, M. Zhao, and B. Xu, "Thermal characteristics simulation of the commissioning process for new buried heated oil pipelines," in Advanced Materials Research vol. 301-303, ed, 2011, pp. 610-616.

[7] D. Hale, "LONGEST CONTINUOUSLY HEATED OIL LINE COMPLETED IN SUMATRA," PIPELINE GAS J, vol. V 209, 1982.

[8] Undisclosed, "SECT Electrical Heating Solutions," ed. jnc-eng.co: SECT.

[9] U. S. F. Service. (2014, 12/05/2014). Uinta-Wasatch-Cache National Forest; Utah; Uinta Express Pipeline Project. [Notice]. Available: https://www.federalregister.gov/articles/2014/01/29/2014-01692/uinta-wasatch-cache-national-forest-utah-uinta-express-pipeline-project#table_of_contents.

[10] B. Guo, S. Song, A. Ghalambor, and T. Ran Lin, "Offshore Pipelines - Design, Installation, and Maintenance (2nd Edition)," ed: Elsevier.

[11] E. W. McAllister, "Pipeline Rules of Thumb Handbook - A Manual of Quick, Accurate Solutions to Everyday Pipeline Engineering Problems (6th Edition)," ed: Elsevier.

[12] K. P. Pigs. Foam Scraper. Available: http://www.pollypig.com/Pages/Foam/Polly%20Pig/Red/Red%20Series.html.

[13] A. S. M. I. H. Committee, "ASM Handbook, Volume 17 - Nondestructive Evaluation and Quality Control," ed: ASM International.

[14] J. A. Johanson. Excessive residue buildup. Available: http://jenike.com/bulk materialtesting/pneumatic-conveying/.

[15] C. GAZ. CIS Scraper. Available: http://www.cisgaz.com/equipment-solutions.

[16] Dees. Gelled Scraper. Available: http://dsetyani.wordpress.com/2012/02/10 /pipeline-inspection-gauge-operation.

[17] A. P. Products. Attachments. Available: http://www.apachepipe.com/resources.html.

Chapter 8

Refining Waxy Crude Oil

Abstract
The goal of the Uinta Pipeline is to safely and easily transport large amounts of waxy crude oil to Salt Lake refineries. The refinement of the waxy crude oil is the final step to consider in the Uinta Express Pipeline project. The refineries are the last step in the process where the crude oil is processed into its usable forms.

There are five refineries that will process oil from the pipeline: the Holly Frontier refinery, Silver Eagle refinery, Chevron refinery, Big West refinery, and Tesoro refinery. The last company, Tesoro, is also the company behind the overall pipeline project. Each refinery is equipped to process the waxy crude oil, but the Holly Frontier, Chevron, and Tesoro refineries are the largest in terms of refining capacity.

The oil is transferred from the pipeline directly into heated storage tanks that keep the oil from solidifying. The actual refining process consists of five main steps that will ultimately break down the waxy crude into usable products. The first two steps, called fractionation and catalytic cracking, separate the heavy oil into lighter substances, called fractions. These fractions are then treated to remove any impurities, and processed into their final products. There are also various miscellaneous operations that take place, including wastewater treatment, further storage of the separated products, and the transportation of the products.

Lastly, the final products are transported from the refineries to locations here in Utah as well as neighboring states. Pipelines are the primary transport method to other states, where the products are stored. Tanker trucks then transport the stored products to their final destinations. Fuel accounts for the most consumed product, including gasoline, jet fuel, and diesel. Other products include light gases like propane and asphalt.

8.1 Waxy Crude Oil

This report provides an overview of waxy crude oil, the refinery process and the refined oil. The proposed Uinta Express Pipeline will increase the amount of waxy crude oil transported to the refineries of North Salt Lake City. Many of these refineries are upgrading to prepare for the increased supply of waxy crude. Once the way crude reaches the refineries, it is stored until it can be refined. Then the refinery process breaks the crude oil apart and mixes it back together in the right proportions to create different products such as gasoline and diesel. The refined oil is transported to neighboring states using a system of pipelines.

The Uinta basin has a vast supply of waxy crude oil that has formed from millions of years of heating and compression of organic materials in the earth. The proposed pipeline will provide five oil refineries in north Salt Lake, Tesoro, Silver Eagle, Holly Frontier, Big West Oil, and Chevron, with up to 60,000 barrels of waxy crude oil per day. To prepare for this amount of oil, the companies have upgraded their refineries to be able to refine more barrels of oil per day and refine this waxy crude.

8.1.1 Formation and Composition

Waxy crude oil, which is also known as petroleum, is a liquid found within the Earth comprised of hydrocarbons, organic compounds, and a small amount of metal. This crude oil is created through the heating and compression of organic materials over a long period of time [1]. Most crude oil found in nature contains a high amount of paraffinic components, which at low temperatures may separate as a wax phase (when it's cold, the paraffinic components cause the oil to become somewhat solid so it can't flow through a pipe) [2]. Figure 1 below shows the steps that the oil has to go through to become the waxy crude oil [3].

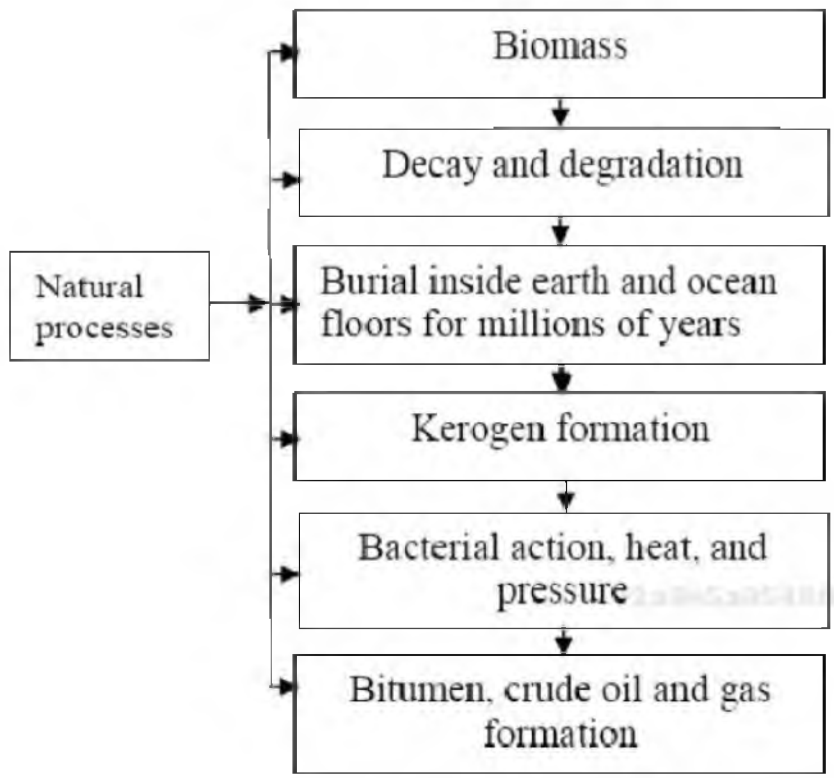


Figure 1: Crude Oil Formation [3]

8.1.2a Tesoro Refinery

The Tesoro Refinery is the biggest refinery in Utah, being able to receive up to 58,000 barrels of crude oil per day. Tesoro is the main company behind the building of the Uinta pipeline. Oil is brought to this refinery from different areas of Utah, Colorado, Wyoming, and Canada. Tesoro manufactures many types of fuels, including jet fuel that will be used at the Salt Lake City International airport. There are multiple supply stations that the Tesoro Network has, most of them being in Utah, and others also in Idaho and Nevada. To get ready for this pipeline, Tesoro upgraded their Utah refinery by expanding their crude oil throughput by 7%. This upgrade project cost Tesoro about $180 million. To allow for this 7% upgrade, Tesoro had to upgrade some of their refining units, like the crude unit, fluid catalytic cracking unit, vapor recovery unit, and distillate desulfurization unit. Also, additional crude storage tanks were added, miscellaneous upgrades in pumps and heat exchangers to handle heavier crude feedstock were done, and an expanded crude unloading unit was added [4].

8.1.2b Silver Eagle Refinery

The Silver Eagle refinery supplies gasoline and diesel to independent marketers throughout the intermountain west [5]. The refinery has a capacity of 15,000 barrels of oil per day. Silver Eagle has no current future plans to upgrade the refinery in Northern Salt Lake.

8.1.2c Holly Frontier Refinery

The Holly Frontier refinery is located in Northern Salt Lake City, and has a crude oil capacity of 31,000 barrels per day. The Holly Frontier refinery plans to expand their Utah refinery from a capacity of 31,000 barrels of oil a day to 45,000 barrels of oil a day as phase one of the project, with phase two expanding the capacity to 60,000 barrels a day [6]. Also the refinery expects incremental yields from the expansion project to be 60% gasoline and 40% diesel [6]. The expansion project is expected to cost around $300 million. This expansion project will increase the refining capacity for crude oils while also producing low-sulfur fuels and reducing emissions. The goal of this expansion project is to utilize local crude oil, increase production, reduce emissions, and provide economic benefits [7].

8.1.2d Big West Oil Refinery

The Big West Oil Refinery has a capacity of 35,000 barrels of oil per day which will supply customers in seven western states. The refinery receives oil from parts of Utah, Wyoming and Canada [8]. Big West Oil does not have plans right now to upgrade the refinery to accommodate all the new oil that will be brought in.

8.1.2e Chevron Refinery

The Chevron Oil refinery has a capacity of 45,000 barrels of oil per day. Chevron plans to upgrade the refinery so it can handle a wider range of locally and nationally produced crudes, which will cost around $83 million. The upgrade will not increase the capacity of the refinery, just allow it to have the ability to refine different kinds of crude oils [9].

8.2 Refining Process

The refinery process begins with transporting the crude oil to the refineries. The pipeline branches off at each refinery and deposits the waxy crude directly into storage tanks. The waxy crude is stored in storage tanks until the refinery can refine it. Then the actual refinery is performed on the waxy crude. Finally the wastewater is purified and environmental issues are mitigated.

8.2.1 Transportation to Refineries

The pipeline is proposed to enter at Bountiful and head west till it connects to the Woods Cross Refinery. The pipeline would then head south to hit the west side of Big West Oil Refinery. It will continue south to reach The Chevron Refinery until finally heading southeast to end at the Tesoro Refinery. Alternatively, the pipeline could enter through Emigration canyon and follow the mountain northwest to the Tesoro Refinery. It would then head north to connect to the east side of Chevron and Big West Refineries. Finally, the pipeline would continue north to end at the Woods Cross Refinery [10].

8.2.2 Storage of Waxy Crude

The storage of waxy crude oil awaiting refinement is more difficult than lighter crude oils. Since waxy crude is solid at regular temperatures, it is heated to keep it in a liquid state. The storage tanks are insulated and kept at a temperature of about 20° F above the waxy crude melting point. Maintaining the correct temperature is critical to the storage of waxy crude oil. If the temperature drops too low then the waxy crude solidifies making it very hard to remove from the tank, but if the temperature is too high then oxidation can occur. Oxidation breaks the crude oil down. Once Oxidation starts, all waxy crude affected is removed or the degradation will continue to spread [11].

Chemicals can be added to the waxy crude to reduce its pour point or improve the flow. There are three types of chemicals that can be added to the waxy crude: wax inhibitors, detergents, and dispersants. A wax inhibitor decreases the amount of crystals and the networks of crystals that form when the waxy crude cools. This will decrease the pour point allowing the waxy crude to flow at lower temperatures. Detergents and dispersants keep the waxy crude from bond to surfaces by keeping the crystals separated. Ethylene-vinyl acetate copolymer (EVA), a wax inhibitor, can reduce the pour point from 26° C to -2° C [12].

Alternatively, to reduce the operating cost of continuously heating the waxy crude, methods of storing the waxy crude as a solid are possible. The solid-phase (gelatinized) storage system is capable of storing the waxy crude at normal temperatures and then heating the wax as needed. A heater is attached to a floating roof and then drains out of a pipe that stays at the same level of the top of the wax. Along with reducing operating cost, there are several other benefits to storing the wax as a solid. During earthquakes the wax does not slosh making it safer than a liquid storage tank hit by an earthquake. There is also less corrosion inside the tank and lower vapor pressure. Finally, the solid wax will not leak out of small cracks and larger spills will not spread out as much as liquid waxy crude [13].

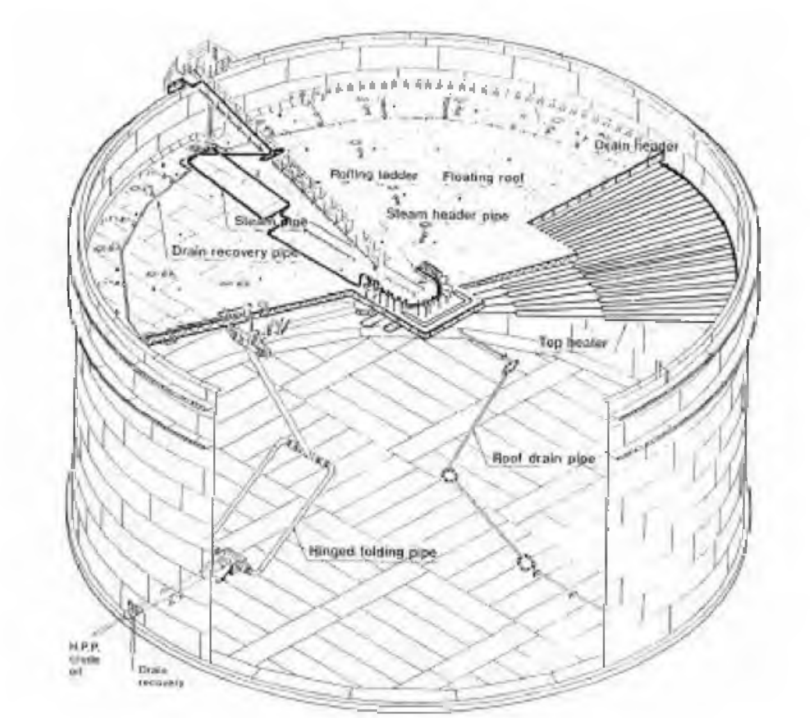


Figure 2: Solid Wax Storage Tank [13].

8.2.3 Steps for Refining Waxy Crude

There are five main steps in refining waxy crude. The first step is fractionation, separating the crude oil into the different hydrocarbon compound that make up the waxy crude. Each hydrocarbon compound has a different boiling point which is used to separate them. The second step is conversion, changing the size of the hydrocarbon compounds. Fluid catalytic cracking is used for waxy crude. The third step is treatment, removing all unwanted impurities in the oil. There are two methods of treatment, chemical and physical separation. The fourth step is formulating and blending, mixing hydrocarbon compounds to produce the final product. The last step is miscellaneous refining operations. This includes operations such as storage, waste water treatment and exporting oil products [14].

8.2.3a Fractionation of the Crude Oil

Fractionation, or fractional distillation, is the process that separates the crude oil into different components, or fractions. There are two main types of crude units used in the distillation process—atmospheric and vacuum.

After desalting occurs, the crude oil is preheated prior to entering an atmospheric crude unit. This tower is kept at pressures just above atmospheric temperature. The crude oil enters the tower near its base, and is immediately heated to temperatures around 650 – 700 F. The lighter fractions vaporize and begin to rise in the tower, while heavier fractions, called residue, remain liquid and stay near the bottom of the tower [14].

As the vapor rises higher in the column, the temperature in the tower decreases. Horizontal trays, kept at different temperatures, are used at various height locations to separate and collect the different components. The exact design of these trays varies, but a common design uses trays with small holes covered with bubble caps, as seen in Figure 3. As the vapor condenses on a tray, it will fill up the tray until the liquid flows over the side and down onto the tray below. The heated vapor flows through the holes, and is better distributed throughout the liquid with the bubble caps. The vapor will cause parts of the liquid to evaporate once again as it passes through trays. This process is repeated to better separate the individual components [15].

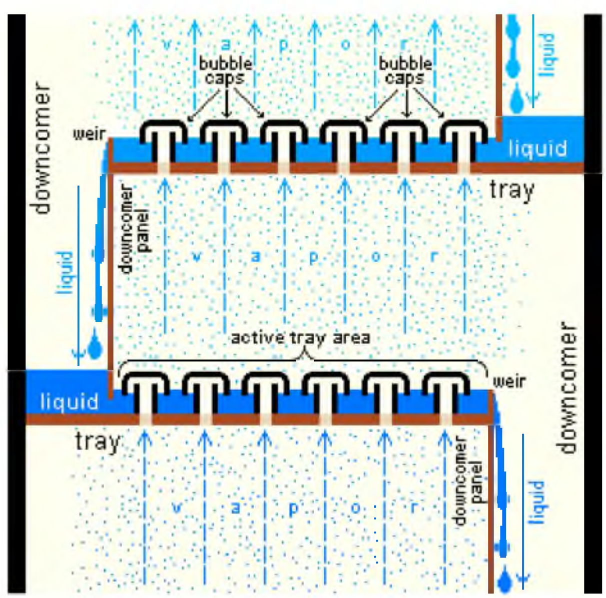


Figure 3: Atmospheric Crude Unit Trays [15].

Fractions are collected from the side, the top, and the bottom of the tower. On the side of the tower, fractions are drawn from trays that have specific temperatures that correspond to a desired product. In many systems, parts of these products are fed back into the tower to further separate. The heavy residue exits the bottom of the unit. Some of the residue is fed back into the atmospheric unit to further separate out the lighter oils, but most will travel to a vacuum distillation unit. At the top of the tower, vapor that does not condense is collected and condensed in another unit. Again, some of this condensed liquid is separated again in the previous tower [15].

The heavier residue that exits the atmospheric unit at the bottom is sent to another distillation tower that is functionally similar to the first tower, but kept at a lower pressure. This lower pressure will make the components of the residue vaporize at a lower than normal temperature, making it possible recover the remaining components. Through the use of trays or other collecting equipment, fractions are again separated and collected. The fractions are primarily collected as light vacuum gas oils (LVGO) and heavy vacuum gas oils (HVGO). The vacuum unit will also have residue at the bottom of the tower [16].

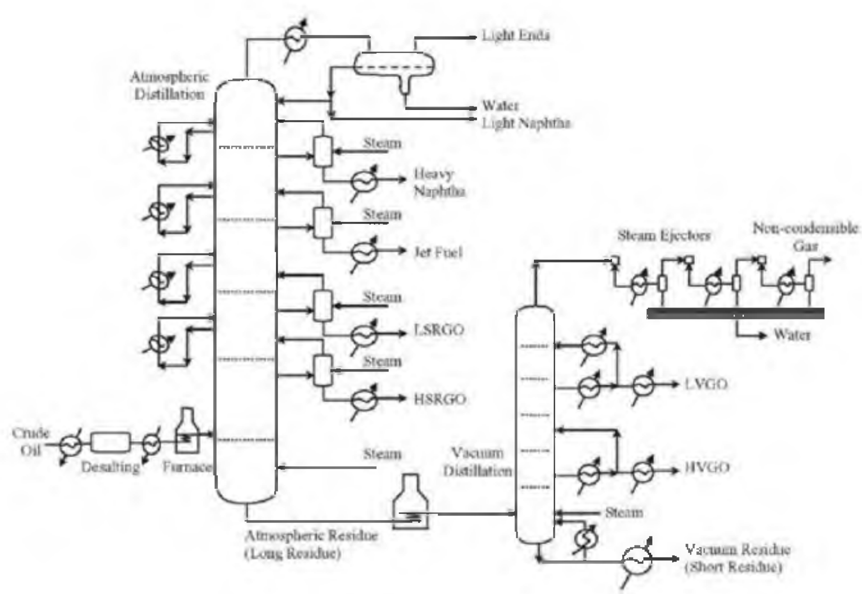


Figure 4: Crude Distillation Unit [16].

Figure 4 shows a possible design for a crude distillation unit. The oil enters the atmospheric distillation tower near the bottom after being preheated. The vapor rises and different fractions condense on the collecting trays as the temperature decreases. The figure shows how these fractions are fed back into the tower to go through the separation process again. The residue that exits the bottom is fed into the vacuum distillation unit and is again separated into different fractions.

8.2.3b Fluid Catalytic Cracking (FCC)

After the distillation process, heavier gas oil that remains can still be altered through the process of fluid catalytic cracking. The method of cracking refers to the process that breaks heavier materials into lighter, usable substances. This process is similar to distillation in that they both result in the breaking of heavy fractions down into lighter fractions. Distillation is a physical process, however, where-as FCC is a chemical process [17].

The oil from the distillers are mixed with a catalyst that has been heated into a vapor. The catalyst can consist of zeolite, nickel, and alumina silicates [3]. The catalyst breaks down the larger molecules into smaller, more desirable molecules, like those that make up gasoline. These smaller molecules are then separated in another fractionating column. The catalyst will over time collect carbon molecules, called coke. This used catalyst is circulated into a regenerator that will burn off the coke, making the catalyst usable again in the cracking process [14] [17].

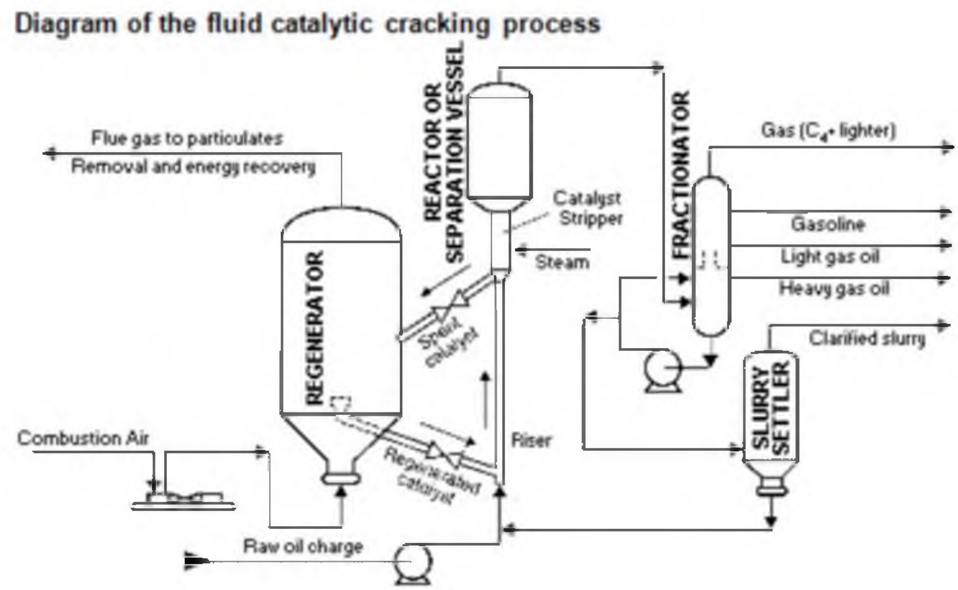


Figure 5: Fluid Catalytic Cracking Process [14].

8.2.3c Treatment

The crude oil then goes through a treatment process to remove all unwanted pollutants. It can either be treated using chemicals or physically separating the pollutants from the crude oil. From The FCCU, the waxy crude is treated using a sweetening process. Sweetening removes sulfur, nitrogen, and dissolved metals. Sweetening is done in several different ways, such as using sulfuric acid to remove the pollutants. This will improve the odor, color and stability of the final product [14].

8.2.3d Formulating and Blending

To achieve the desired properties from the final products, the different hydrocarbon compounds or cuts are mixed. Gasoline, diesel, jet fuel, and kerosene are blended by the adding specific amounts of cuts to the main pipe where they are all mixed. Other chemicals such as anti-oxidants, rust inhibitors and octane enhancers are added to improve the final product [14].

The cuts from the crude oil are divided by their boiling points ranging from -76.5 F to 1292 F creating 64 different cuts. Each cut has unique properties such as specific gravity, viscosity and octane number. The properties of the mixed product can be determined by using the properties of all the cuts that were mixed. The property of the cut is multiplied by the volumetric fraction of the cut, and is done for every cut used in the mix. The sum of all the cuts creates a weighted average that estimates the final product's properties [18].

8.2.3e Miscellaneous Refinery Operations

During the refinery process, water is polluted with hydrocarbons and other contaminants that needs to be treated before it leaves the refinery. The first step is to remove the hydrocarbons from the water. This is done by using gravity to separate the oil and water. Since the oil has a lower specific gravity than water, the oil will float to the surface. The oil is then skimmed off the surface of the water. After that the water is filtered to remove any solids. The second step is to treat the oxidized soluble organic matter in the water by using activated sludge, trickling filter or anaerobic treatments. The third step is to remove the remaining pollutants by reverse osmosis, ion exchange and ozonation. Oxygen is added to the water to oxidize remaining chemicals in the water. This will also bring the oxygen content of the water to the required level [14].

8.2.4 Pollution Caused by refining

Crude oil is a non-toxic natural and biodegradable product but the way that is it refined causes the main environmental issues. The refined oil is hard to biodegrade and is toxic to all living things. During the refining process, the use of highly toxic chemicals and catalysts are used to break down the hydrocarbons, creating serious environmental issues. These chemicals and catalysts will contaminate the air, land, and water that becomes exposed to it [3]. Some air pollutants emitted by refineries are sulfur dioxide, oxides of nitrogen, carbon monoxide, and particulate matter [19]. Lead, for example, is one catalyst that cause air pollution. When gasoline is burned lead particles are emitted into the air and becomes oxidized, which creates lead oxide, a poisonous compound. Incidentally, the main cause of water pollution caused by the refining process contains heavy metals such as mercury and chromium [3].

8.2.5 Preventing Environmental Issues

To prevent these environmental issues that the refining process of oil causes, non-toxic chemicals and catalysts need to be used. The use of natural chemicals and catalysts need to be used to prevent this pollution from happening. Some natural catalysts such as zeolites, natural alumina silicates, amorphous and crystalline silica alumina catalyst, clay, and others could be used and will not produce the unwanted pollution [3]. Also, finding a way to use the natural crude oil as a fuel would eliminate all the pollution that is produced during the refining process.

8.3 Refined Oil

After the waxy crude is refined into usable products, it is transported to neighboring states through a system of pipelines. The price of the final products are dependent on the price of the waxy crude, taxes, refining, and distribution. Most of the waxy crude is refined into gasoline, diesel, jet fuel, or asphalt.

8.3.1 Petroleum Products Final Destination

Most of the oil refined by Tesoro stays fairly close to Salt Lake City. The refinery exports to Idaho, Utah, Nevada, Wyoming, and Washington. The jet fuel produced by the refinery is shipped to the Salt Lake City International Airport [20]. Wood Cross refinery also sells its products in Utah, Idaho, Nevada, Wyoming, and eastern Washington [7]. Big West Refinery ships its refined products to seven western states [8]. Most of the refined oil is shipped via pipeline to a temporary storage and then a tanker truck delivers to its final destination. Salt Lake City has pipelines connecting Idaho, Wyoming, Colorado, and Nevada, and are mapped in Appendix V.

8.3.2 Price of Petroleum Products

The costs of the refined petroleum products are dependent on several variables. The cost of the waxy crude represents about 68% of the average cost for gasoline. The final 32% is a combination of taxes, refining, and distribution and marketing at 12%, 11% and 9% respectfully [21]. Petroleum products, like stocks, are sold on exchanges such as the New York Mercantile Exchange (NYMEX). The NYMEX evaluates where the product is sold and the type of petroleum product to determine the final price. Although the price of the waxy crude is the biggest impact on the final prices, there are several other variables that can impact the final prices, such as severe weather or new environmental mandates. The future prices can also affect the current price of petroleum products. If the price is expected to rise, companies begin stockpiling petroleum products to reduce the supply and raise prices [21].

8.3.3 Commercial Crude oil products

Gasoline accounts for nearly half of the crude oil products produced by U.S. refineries. Depending on the composition of the crude oil, one 42 gallon barrel of crude will produce roughly 19 gallons of gasoline, which is used primarily in car engines, and accounts for the highest crude product consumption in the U.S. [22]. After gasoline, diesel fuel is the next largest product from crude oil. Due to diesel containing more energy per gallon compared to gasoline, it is important to the U.S. economy. It is used in most trains, buses, boats, freight trucks, construction vehicles, and other vehicles. Diesel generators are also widely used as backup powers supplies for buildings, like hospitals. Heating oils are similar to diesel, but contain high amounts of sulfur, making it too harmful to burn in engines. From one barrel of crude oil, about 13 gallons are diesel or heating oil's [22].

Jet fuel accounts for around 4 gallons of a crude barrel, and the next highest petroleum consumption in the U.S. After that in terms of consumption are liquefied petroleum gases (LPG). Propane and other gases are important in the U.S. Propane is primarily used in homes, for heating and cooking purposes for example, but it is also used as an alternative fuel source [22].

Asphalt, used in roadway pavement and roofing, is produced from the heaviest residue that remains from the distillation towers. Naptha is a lighter fraction that is treated and turned into heavy and light naptha. Paraffin wax is a type of naptha used in products like candles and crayons. Teflon is also produced from naptha [23]. Figure 12 in Appendix VI summaries possible products derived from crude oil.

8.4 Conclusion

The building of the Uinta Express pipeline will bring in thousands of barrels of waxy crude oil per day to the five refineries in Northern Salt Lake. To get ready for this amount of oil Tesoro, Chevron, and Holly Frontier have expanded their Northern Salt Lake refineries, upgrading the capacity the refineries can handle and the equipment used for this special oil. The waxy crude oil will go through the four refining steps, eventually being turned into the needed fuel that drives today's society. The refined fuel will then be distributed throughout the state and to neighboring states around Utah.

8.5 References

[1] "What is Crude Oil? A Detailed Explanation on this Essential Fossil Fuel," www.oilprice.com. [Accessed November 17, 2014].

[2] A. Fasano, L. Fusi, and S. Correra, Mathematical Models for Waxy Crude Oils, Overviews and tutorials, Kluwer Academic Publishers, May 2003.

[3] A. Chhetri and M.R. Islam, "A Pathway Analysis of Crude and Refined Petroleum Products." Dalhousie University, Faculty of Engineering, Halifax, Canada, 2012.

[4] "Tesoro Salt Lake City Refining Project." http://abarrelfull.wikidot.com/tesoro-salt-lake-city-refinery-project. [Accessed December 9, 2014].

[5] "About Silver Eagle Refining." http://silvereaglerefining.net/about/. [Accessed November 19, 2014].

[6] "HollyFrontier Announces Salt Lake City Refinery Expansion & Feedstock Supply Agreement" http://investor.hollyfrontier.com/releasedetail.cfm?ReleaseID=637104. [Accessed November 19, 2014].

[7] "Woods Cross Refinery."http://www.hollyfrontier.com/woods-cross/. [Accessed December 9,2014].

[8] "North Salt Lake Refinery." http://www.bigwestoil.com/wordpress/north-salt-lake-refinery. [Accessed November 30, 2014].

[9] "Chevron refinery upgrade is third planned for Salt Lake City." Salt Lake Tribune, March, 2012. www.sltrib.com. [Accessed December 8, 2014].

[10] "The Route," Unita Express Pipeline, 2014. [Online]. Available: http://uintaexpresspipelin e.com/ the-route. [Accessed: Dec. 03, 2014].

[11] "Wax Handling Instructions" American Fuel and Petrochemicals Manufacturers. Available: http://www.afpm.org/Wax-Handling-Instructions/.

[12] J. B. Taraneh, G. Rahmatollah, A. Hassan, and D. Alireza, "Effect of wax inhibitors on pour point and rheological properties of Iranian waxy crude oil," Fuel Processing Technology, vol. 89, pp. 973-977, 10//2008.

[13] "Solid-phase (Gelatinized) Storage System of Waxy Crude Oil," Transactions of the Iron and Steel Institute of Japan, vol. 26, pp. 1093-1093, 1986.

[14] Occupational Safety and Health Administration, OSHA Technical Manual, 1999. [Online]. Available: https://www.osha.gov/dts/osta/otm/otm_iv/otm_iv_2.html, [Accesed: Dec. 03, 2014].

[15] "Crude Distillation." CI Engineering. [Online]. Available: http://www.cieng.com/a-111-355-ISBL-Crude-Distillation.aspx, [Accessed Nov. 30].

[16] "Guide to Refining." CHE Resources, 2010. [Online]. Available: http://www.cheresources.com/content/articles/energy/a-students-guide-to-refining, [Accessed Nov. 30].

[17] "Fluid catalytic cracking is an important step in producing gasoline," U.S. Energy Information Administration, December 11, 2012. [Online]. Available: http://www.eia.gov/todayinenergy/detail.cfm?id=9150, [Accessed Dec. 08].

[18] S. Parkash, Refining Processes Handbook. Amsterdam: Gulf Professional Pub, 2003.

[19] H. Wansbrough, Refining Crude Oil, refining process for crude oil, The New Zealand Refining Company Ltd. [Accessed November 17, 2014].

[20] "Tesoro Fact Sheet," March 24, 2014. [Online]. Available: http://tsocorpsite.files.wordpress. com/ 2014/08/slcfact.pdf. [Accessed: Nov, 17, 2014].

[21] American Petroleum Institute, "Understanding Crude Oil and Product Markets," American Petroleum Institute, 2014. [Online]. Available: http://www.api.org/oil-and-natural-gas- overview/~/media/Files/Oil-and-Natural-Gas/Crude-Oil-Product-Markets/ Crude-Oil-Primer/Understanding-Crude-Oil-and-Product-Markets-Primer-Low.pdf. [Accessed: Dec 01, 2014].

[22] "Oil: Crude and Petroleum Products Explained." U.S. Energy Information Administration. [Online]. Available: [Accessed Nov. 30].

[23] "Products Made from Crude oil and Other Uses for Crude." Rig Source Inc, July, 2014. [Online]. Available: http://www.rigsourceinc.com/news/crude-oil-products [Accessed Dec. 08, 2014].

[24] U.S. Department of Transportation, "Gas Transmission and Hazardous Liquid Pipeline," National Pipeline Mapping System, 2013. [Online]. Available: https://www.npms.phmsa.dot.gov/Documents/NPMS_Pipelines_Map.pdf. [Accessed: Dec 06, 2014].

Appendix I

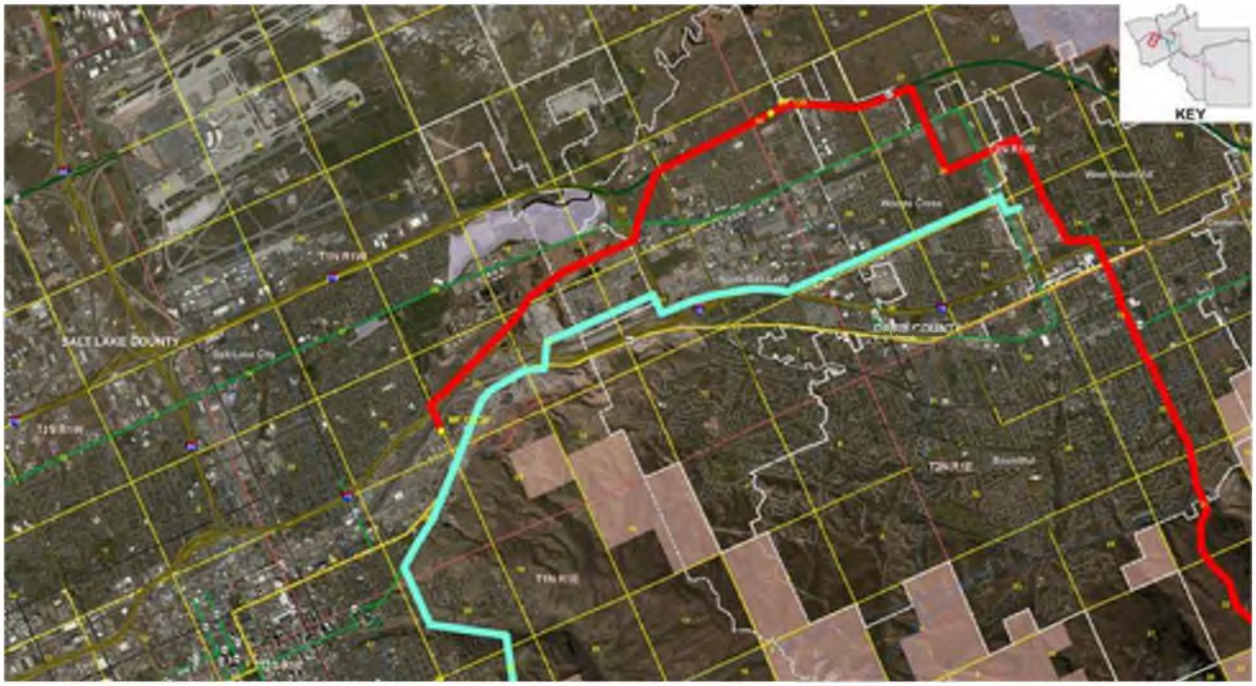


Figure 6: Map of route through Northern Salt Lake [10].

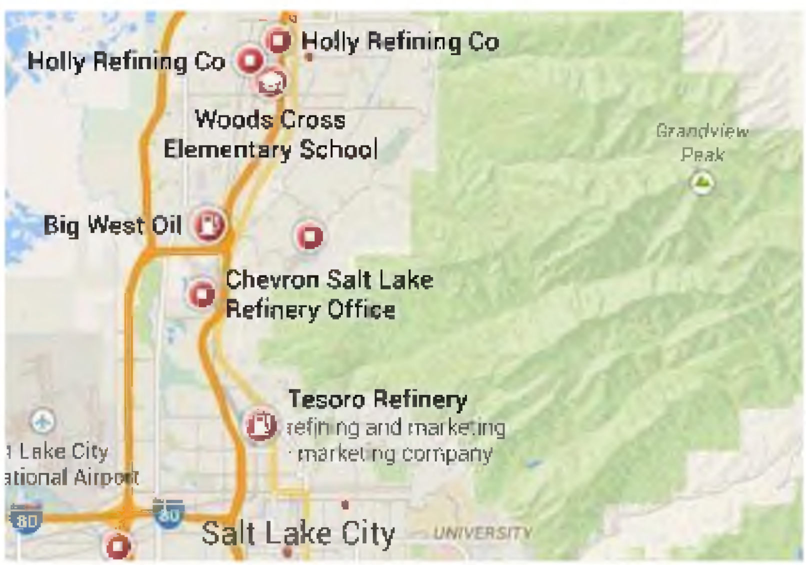


Figure 7: Locations of Refineries [Google Maps].

Big West Oil, LLC

333 W. Center Street
North Salt Lake, UT 84054

Crude Oil Purchase Information
Edward Hatch
edward.hatch@bigwestoil.com

Crude Oil Price Bulletin Information
Rex Anne Bock
rexanne.bock@bigwestoil.com
www.bigwestoil.com

Effective Month	Utah Yellow Wax*	Utah Brown Wax	Utah Black Wax*	Southwest Wyoming Sweet (1)**	NYMEX Calendar Average	NYMEX Trading Day Average
January	$77.3439	$77.0213	$77.0213	$85.8439	$94.8439	$94.8567
February	$82.9596	$82.4596	$82.4596	$91.4596	$100.4596	$100.6753
March	$83.1797	$82.2442	$82.2442	$91.6797	$100.6797	$100.5090
April	$84.7197	$83.7197	$83.7197	$93.2197	$102.2197	$102.0348
May	$84.3384	$83.3384	$83.3384	$92.8384	$101.8384	$101.7948
June	$87.6977	$86.6977	$86.6977	$96.1977	$105.1977	$105.1467
July	$84.9806	$83.9806	$83.9806	$93.4806	$102.4806	$102.3918
August	$78.7123	$77.7123	$77.7123	$87.2123	$96.2123	$96.0762
September	$75.9400	$75.0567	$75.0567	$84.0900	$93.0900	$93.0343
October	$67.4658	$66.4658	$66.4658	$75.4658	$84.4658	$84.3391
November	$58.6473	$57.6473	$57.6473	$66.6473	$75.6473	$75.8100
2014	**$78.7259**	**$77.8494**	**$77.8494**	**$87.1032**	**$96.1032**	**$96.0608**

(1) Carbon, Lincoln, Sublette, Sweetwater, and Uinta counties.

This bulletin shows prices and gravity adjustments posted by Big West Oil, LLC (Big West) for purchases of crude oil and condensate. Prices are based on the use of 100% mutually acceptable automatic measuring equipment with customary adjustment of volume and gravity for tank tables or temperature and full deduction for basic sediment and water.

Effective 7:00 a.m. on the date(s) indicated, and subject to change without notice and subject to the terms and conditions of its division orders or other contracts, Big West will pay the shown prices for merchantable crude oil and condensate delivered for its account into the facilities of its authorized receiving agency. Merchantable crude and condensate is defined as virgin crude and/or condensate produced from wells which is free of injected or outside foreign contamination, added chemicals containing, but not limited to, halogenated organic compounds and oxygenated compounds and which is fit for normal refinery processing. Seller warrants that the crude oil and condensate delivered to Big West shall be merchantable quality as defined above and fit for refinery use. Prices are shown for oil at 40.0 degrees API gravity, except as noted.

* Specified crude types are subject to a deduction of $0.015 per each 0.1 degree of gravity below 40.0 degrees and per each 0.1 degree gravity above 44.9 degrees.

** Specified crude types are subject to a deduction of $0.015 per each 0.1 degree of gravity below 40.0 degrees and per each 0.1 degree gravity above 49.9 degrees.

Figure 8: Crude Oil Cost [8].

Appendix III

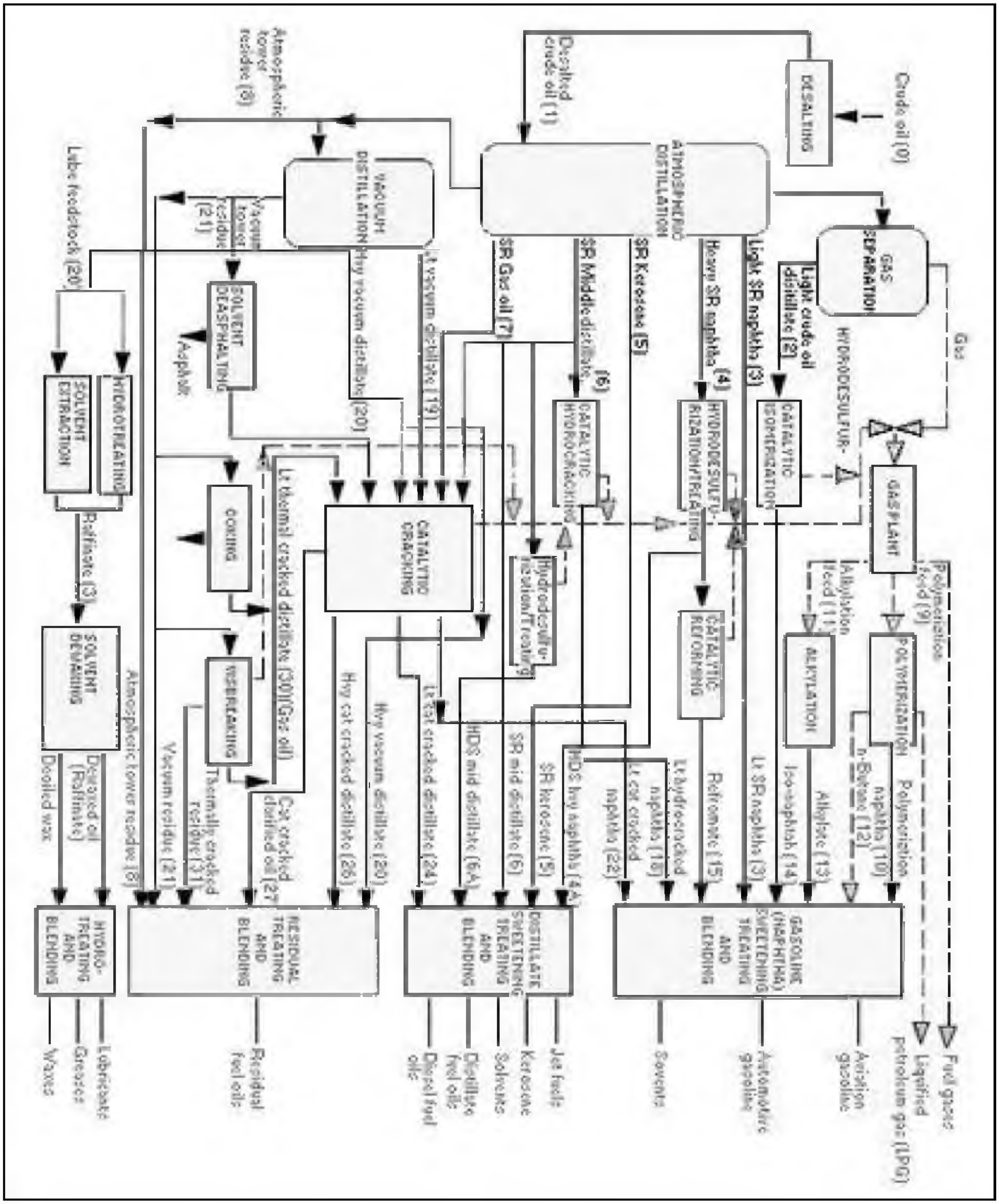


Figure 9: Refinery Process [14].

Appendix IV

CUT INDEX	CUT NAME	TBP TEMPERATURE END, °F
1	H_2S	−76.5
2	H_2	−422.9
3	C_1	−258.7
4	C_2	−127.5
5	C_3	−43.7
6	IC_4	10.9
7	NC_4	31.1
8	CUT NC4–100°F	100
9	CUT 100–120	120
10	CUT 120–140	140
11	CUT 140–160	160
12	CUT 160–180	180
13	CUT 180–200	200
14	CUT 200–220	220
15	CUT 220–240	240
16	CUT 240–260	260
17	CUT 260–280	280
18	CUT 280–300	300
19	CUT 300–320	320
20	CUT 320–340	340
21	CUT 340–360	360
22	CUT 360–380	380
23	CUT 380–400	400
24	CUT 400–420	420
25	CUT 420–440	440
26	CUT 440–460	460
27	CUT 460–480	480
28	CUT 480–500	500
29	CUT 500–520	520
30	CUT 520–540	540
31	CUT 540–560	560
32	CUT 560–580	580
33	CUT 580–600	600
34	CUT 600–620	620
35	CUT 620–640	640
36	CUT 640–660	660
37	CUT 660–680	680
38	CUT 680–700	700
39	CUT 700–720	720
40	CUT 720–740	740
41	CUT 740–760	760
42	CUT 760–780	780
43	CUT 780–800	800
44	CUT 800–820	820
45	CUT 820–840	840
46	CUT 840–860	860
47	CUT 860–880	880
48	CUT 880–900	900
49	CUT 900–920	920
50	CUT 920–940	940
51	CUT 940–960	960
52	CUT 960–980	980
53	CUT 980–1000	1000
54	CUT 1000–1020	1020
55	CUT 1020–1040	1040
56	CUT 1040–1060	1060
57	CUT 1060–1080	1080
58	CUT 1080–1100	1100
59	CUT 1100–1120	1120
60	CUT 1120–1140	1140
61	CUT 1140–1160	1160
62	CUT 1160–1180	1180
63	CUT 1180–1200	1200
64	CUT 1200–1292	1292

Figure 10: Different Compounds from FCC [18].

Appendix V

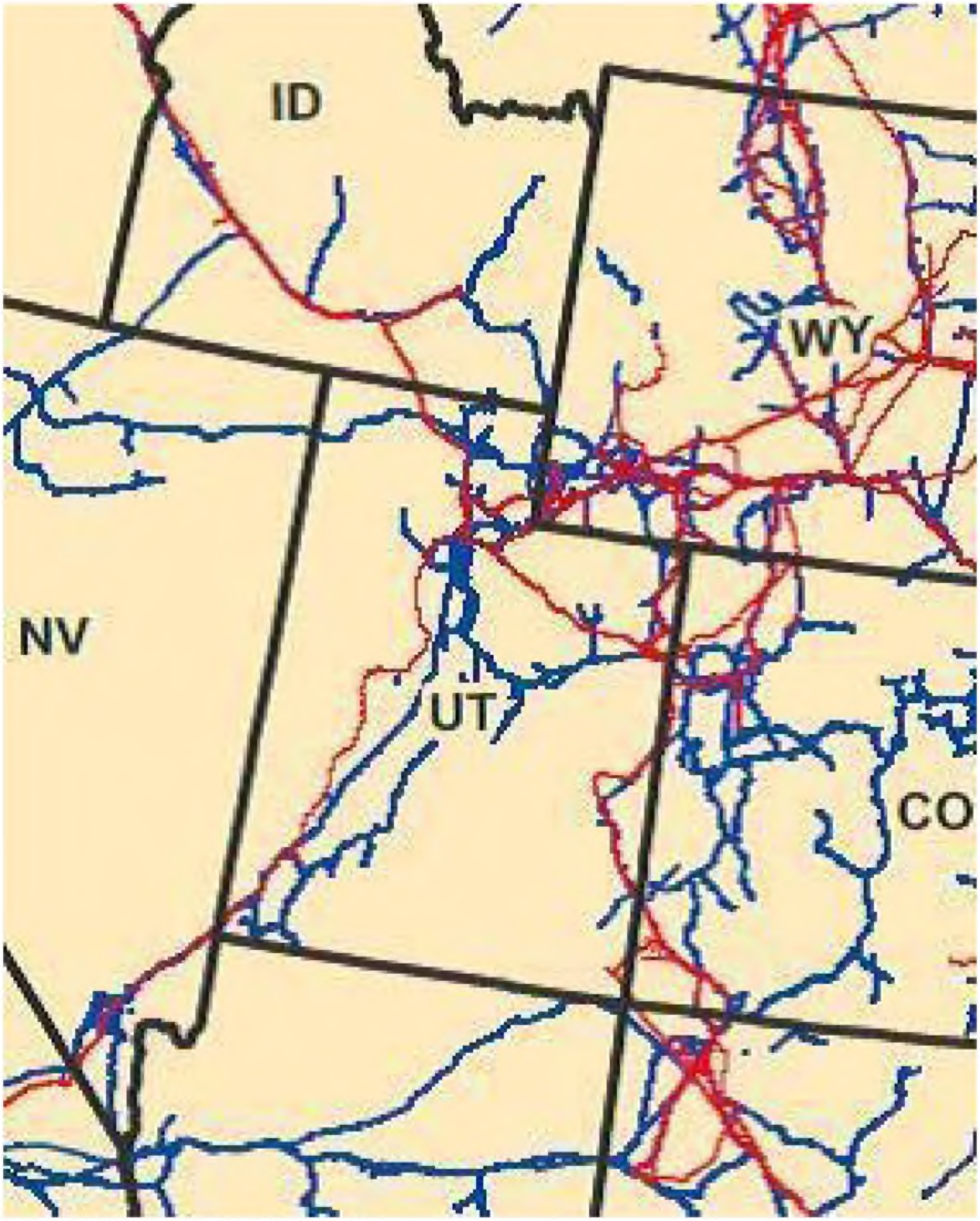


Figure 11: Pipelines in Utah [24].

Appendix VI

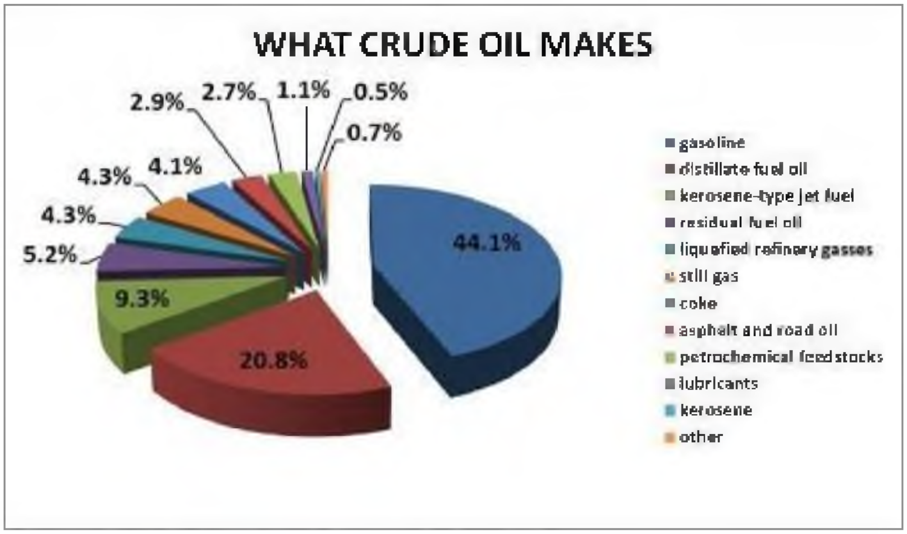


Figure 12: Fuels from Crude Oil [21].

[This page intentionally left blank.]